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Third national conference on wheat utilization research

Held at Manhattan Kansas
November 5—7 1964

AGRICULTURAL RESEARCH SERVICE, U.S. DEPARTMENT OF AGRICULTURE

THE THIRD NATIONAL WHEAT UTILIZATION RESEARCH CONFERENCE was held November 5 to 7, 1964, in Manhattan, Kansas, with Kansas State University as host. Dr. Glenn H. Beck, the University's Dean of Agriculture, warmly welcomed the attendants. Organizations and personnel responsible for program and arrangements were mentioned by Mr. Howard Morton. His speech and those that followed are included in this report.

Objectives and long-range hopes for annual wheat utilization research conferences were summarized in the Foreword of the report of the first conference. The major objective continues to be a comprehensive working organization, including all segments of the wheat industry, along with scientists engaged in research. The hope that activates the conferences is that exchange of information will continue to aid and guide all concerned and that improvements will continue to be made. Everyone whose work involves wheat realizes that this crop is a large factor in the world economy and in the health and peace of the world.

The Fourth National Conference on Wheat Utilization Research will be held in Boise, Idaho, November 3 to 5, 1965.

This report was prepared in the Western Regional Research Laboratory, Albany, California 94710 -- headquarters of the Western Utilization Research and Development Division of the U. S. Department of Agriculture's Research Service. Those interested in reproduction must obtain permission from the speaker or his organization. Occasional mention of commercial products does not imply recommendation.

Copies are available on request. In addition copies of the reports of the first and second conferences and of an earlier one on "Role of Wheat in the World's Food Supply" are also available.

April, 1965

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BACKGROUND AND OBJECTIVES OF THE CONFERENCE

Howard Morton
Director of Utilization Research, Great Plains Wheat, Inc.

The mountain men of the fur trade used to rendezvous once a year along the Green River. They told tall tales, drank raw whiskey, gambled, fought, and traded. The important exchange was information. Where had trapping been good? What Indian tribes were friendly? Where were the easiest mountain passes? What was the price of pelts in St. Louis? Could you get good horses at the California haciendas? Success hung on information.

Those men were a varied lot: adventurers, drifters, breadwinners supporting families, and plungers in business enterprise risking their lives in support of their investments. The analogy is not absolute, but the National Wheat Utilization Conference makes me think of it as a 20th century rendezvous. We have widely varied interests, but we are here for a unifying purpose. We will renew acquaintances, have an occasional social drink, and argue points of difference. We will exchange information and some of the information will help to set our course for next year.

Two facts explain the origin of these conferences and justify their continuation. First, economic developments are bringing the farmer into closer association with those who provide his services and equipment, on the one hand, and those who process and market his products. Second, research is the prime mover in all segments of our economic structure.

In response to a resolution of the National Association of Wheat Growers, a meeting was held at the Western Regional Research Laboratory in Albany, Calif. early in 1962. Under joint sponsorship of that association, Western Wheat Associates, Great Plains Wheat, Inc., Western Regional Research Laboratory, and other Department of Agriculture agencies, the conference was titled, "The Role of Wheat in the World's Food Supply." Scientific, economic, and humanitarian aspects of this segment of the total wheat utilization picture were examined and discussed. A very clear community of interests from many backgrounds, focused on wheat utilization was revealed. It was determined that subsequent meetings would be held on the common meeting ground of research on wheat utilization.

The First National Wheat Utilization Research Conference was held at the University of Nebraska with added sponsorship of the Northern Regional Research Laboratory, the Nebraska Wheat Commission, the Nebraska Wheat Growers Association, and the Nebraska State Agricultural Experiment Station. The second conference was held last year in Peoria, Ill., hosted by the Northern Regional Research Laboratory. The interest attached to those meetings and the assembly here today attest support for continuation.

This year we have continued the informal procedures of the first two conferences by calling a Program Committee to develop details of the program and asking the host to make arrangements. I wish to thank Director C. Peairs Wilson of the Kansas Agricultural Experiment Station, John Kitchens of the State Extension Service, and Professor John Shellenberger and his staff in the Department of Flour and Feed Milling Industries here at Kansas State University for the excellent arrangements.

On the Program Committee we have had the valuable services of Director M. J. Copley of USDA's Western Regional Research Laboratory; F. R. Senti, former Director of the Northern Regional Research Laboratory and now Deputy Administrator of the Agricultural Research Service for Nutrition, Consumer and Industrial Use Research; Dr. J. W. Pence, Western Regional Research Laboratory; Dr. R. J. Dimler, Northern Regional Research Laboratory; Dr. John Matchett and Dr. Wayne Bitting of the Product and Process Evaluation Staff of the Agricultural Research Service; Del Pratt, The Pillsbury Company; Dr. William B. Bradley and Dr. Welker Bechtel of the American Institute of Baking; Dr. Paul Mattern of the Wheat Quality Laboratory at University of Nebraska; Dr. Mark Barmore of the Wheat Quality Laboratory at Washington State University; Ken Gilles, North Dakota State University; John Shellenberger of Kansas State University; Dick Lewis from Nebraska, with Great Plains Wheat, Inc.; Cap Mast of the Millers National Federation; and Bob Olson, Western Regional Research Laboratory. Bob has served as secretary of the committee. Since Fred Senti was called to Washington, Cliff Witham, Acting Director, Northern Regional Research Laboratory, has served the committee also. To all of these I express thanks. The success of this meeting will be in large part due to their efforts and enthusiastic support.

This brief statement of historical development of the conferences implies the principal objectives of these meetings. The more important objectives include the following:

(1) To provide a meeting ground for farmers, processors, and merchandisers to discuss problems of mutual interest and review developments concerning the utilization of wheat in the broadest sense of the word utilization.

(2) To provide a sounding board for reporting research progress on wheat utilization.

(3) To provide an opportunity for scientists to coordinate activities so that the limited funds available for wheat utilization research will provide the greatest results by prevention of unnecessary duplication and by immediate incorporation of research results into projects wherever they will be useful without the usual delays caused by publication lags.

(4) To provide a feedback of commercial information and opinion to scientists conducting research on wheat utilization.

That is one way to look at our objectives and may even be the conventional way. To me, however, there is an overriding objective that is very much a foundation for this meeting. It is to provide markets for all the wheat that can be efficiently produced by American agriculture. In recent years we have been speaking mostly of a solution for temporary surpluses from curtailed acreages. We must gear our thinking however, to some 70 million acres and 1.8 billion bushels of wheat. We must bring strength to our nation

and the world by full use of our resources, particularly those of the soil that are, with careful husbandry, renewable.

If we are to achieve this large increase, we must explore all the processing and marketing possibilities. We must not confine ourselves to economic patterns and price structures of this day. We must see the long view ahead. We should develop a range of food, feed, and industrial products that is limited only by the technological possibilities of wheat as a raw material. In converting wheat to a wide range of products, the maximum returns may come only from a product-byproduct concept. For some products wheat might be used in competition with low-priced raw materials. For such purposes wheat would be used only if it carries a lower price than is feasible for the bulk of the crop. The current wheat program goes along this road to some extent. We do not yet have a complete freedom of flow into certain industrial uses of wheat and non-food mill runs. An optimum balance of multipriced wheat should describe quality of product and should operate to the long-range benefit of farmer, processor, and consumer. Such a balance will be difficult or impossible to achieve until market capacity comes closer to production capacity than at present. However, in the development of new and improved products and processes, we should not trap ourselves by the limitations of today's market and the economic circumstances of this time.

CHANGING OUTLOOK OF RESEARCH IN THE USDA

Nyle C. Brady
Director of Science and Education, USDA, Washington, D. C.

I appreciate the opportunity of meeting with this group to discuss the changing outlook of research in the Department. As a matter of fact, "change" has been a significant part of agriculture since the beginning of our country. The earliest settlers brought their crops and livestock from the homeland and adapted them to the new land and climate. The first American farmers learned from the Indians and improvised their own methods.

From the time of the American Revolution, pioneer farmers began pushing westward. They learned to carve out their farms from the heavy timberlands. They developed techniques of selecting soils on the basis of kind of forest growth that covered them. By the early 1860's agriculture had spanned the continent. But it was already apparent that if the economy was to develop in line with the dreams and plans of her leaders, then something had to be done to bolster the productivity of agriculture.

At that time, 60% of the labor force was required on farms to produce food and fiber for the Nation. About 600 farm societies had been formed to discuss ways to improve productivity. President Abraham Lincoln was thoroughly and publicly committed to fulfilling this need . . . in fact, he ran for office with that plank in his platform. And so, to develop more efficient farm production, the U. S. Department of Agriculture and the Land-Grant College System were both created by the Congress in 1862.

When the Land-Grant Colleges first opened their doors, they came face to face with the fact that they had little scientific information to teach in agriculture. Some States began immediately to establish experiment stations to develop the knowledge they needed. In 1887 the Congress passed the first of several Acts making Federal grants available. The first allotment was $15,000 for each State to help establish and support an experiment station as a department of the agricultural college. These funds have been continued and increased throughout the years, administered by USDA, to support a working partnership in agricultural research.

This partnership has shown productive results. State and Federal scientists have changed the plants that farmers grow in their fields. They have supplied new germ plasm and adapted foreign crops to our climate and methods of farming. They have fixed resistance to various diseases and insect pests in established crops, and tailored many plants to fit machine operations on the farm. As a result, farmers today are planting almost none of the varieties they depended upon 25 to 30 years ago. They have made a change of about 88% in wheat varieties. They've made a change of 99% in varieties of corn, soybeans, and flaxseed--just to give a few examples.

In livestock research State and Federal scientists have developed improved breeds that make more efficient use of feeds and yield better-quality meat, milk, and eggs. They developed hybrid and meat-type hogs. They tailormade a smaller turkey for the modern family. These changes have brought us to the point where we have today the most efficient agriculture ever known at any time, at any place, in the history of mankind. Fewer and fewer farmers are feeding more and more people every year--and providing a better national diet at the same time. Today, one farm worker feeds 31 people, compared to only 5 in 1862. Putting it another way . . . out of every 100 people employed in this country, 8 are working on farms, compared to 60 in 1862. These workers are providing us with the cheapest food on earth. We pay less than 19% of our family income for food today . . . compared to 30, 40, or even 50% in other countries.

Let's consider what has happened in the last 15 years. Transportation costs have increased 52%, housing costs 35%, rent 47%, and medical care 69%. But food cost increase in this period was only 24%. And so we see that change brought about by science and technology has kept almost all agricultural products competitive in our economy. These changes have improved efficiency of production and provided new or enhanced quality of products, such as wash-wear, flameproof, and now <u>stretch</u> cottons, washable non-shrink woolens, and many other examples.

Change is the very essence as well as the objective of research. The scientist has never accepted his environment as the best that can be devised. He knows that through change, we can solve more problems, and make the <u>good</u> better. So in agricultural research we are still changing. We are planning new and expanded programs, both in USDA and in the State experiment stations. One of these important expansions is in utilization research.

I am sure that we share with you a full understanding of the value of utilization research--to agriculture, to consumers, and to the entire economy. In fact, it has been estimated that benefits to the Nation's economy in recent

years have amounted to a $25 return for each dollar spent on utilization research. Today, our utilization research needs no justification. It is stronger than ever before and more progressive and imaginative. We have the full and continuing support of Congress and industry. And we have every reason to believe that the work will continue to expand.

For example, Congress has provided $9.5 million for the Agricultural Research Service to build a new Southeastern Utilization Research Laboratory. The site is Athens, Georgia, and plans for construction are underway. When completed--by the end of 1967--the new building will accommodate from 200 to 225 professional personnel. This laboratory will provide modern research and pilot-plant facilities for a concerted effort to find new, improved uses of poultry and eggs, fruits and vegetables, and other farm commodities of the Southeastern region. This will be the first new regional utilization laboratory to be constructed since the original four were established in 1940 . . . at Philadelphia, New Orleans, Peoria, and Albany, California. We felt this new laboratory had a high priority because the Southeast is rapidly shifting to a diversified agriculture, with increasing emphasis on commercial-scale processing of products. In addition, $4.5 million will be used to improve the facilities of the Northern Utilization Research Laboratory at Peoria, Illinois. Another $4.5 million will be divided equally among the other three to be used for construction, alteration, and equipment. In addition to the regular utilization appropriations, the Congress provided $3.1 million in special funds to conduct research in certain problem areas. For example, $650,000 of these funds will be used for utilization research on cereals; $500,000 on cotton and cottonseed; and $500,000 for research on animal products.

One project involves $350,000 to be used for special research on molds... starting first with those found on peanuts, soybeans, cereals, and cottonseed. This is part of the Department's effort to combat an unforeseen problem that has recently arisen with regard to peanuts, and is a potential threat with other plants. We have known for a long time that moldy plant material could be toxic to animals. But in 1960, a specific toxic substance was isolated and identified in moldy peanuts. Known as aflatoxin, it is part of a group called mycotoxins. They are produced as byproducts of certain molds, much in the same way that useful antibiotics are produced. A few cases of poisoning in animals have been traced directly to the consumption of moldy peanuts containing aflatoxin, but there are no known cases of illness in humans from this source. However, the Government is cooperating with industry in a broad research program related to plant molds. The objectives are to eliminate molds entirely or at least make sure that moldy portions of any commodity are not used for food or feed.

We are making an educational effort to aid farmers in using practices which may be helpful in improving the quality of their crops, particularly by better handling at harvest. Educational programs will also emphasize the maintenance of quality through all handling and processing procedures. The new million-dollar peanut marketing laboratory at Dawson, Georgia, will be a helpful addition. It should be ready for operation some time in 1966. We're planning the program, aimed at developing ways to improve handling and storage of peanuts during marketing so as to maintain their quality from farms to consumers.

Another broad research program aimed at consumer protection is the study of health-related problems of tobacco. We are directing these research efforts toward first, identifying compounds in tobacco that may be responsible for human health problems, if any, and second, if this is true, finding the means of reducing or eliminating them. We are stepping up our efforts within the Department and also in cooperation with interested States. For example, Congress recently appropriated $675,000 for use in North Carolina to increase research on tobacco as related to human health and another $1.5 million for this purpose in Kentucky.

Federal and State scientists are attempting to isolate and identify such organic compounds as the various phenols in tobacco leaf and smoke. You may recall that the Surgeon General's report on smoking and health cited phenols as having a possible indirect effect on health. Tobacco varieties can be developed that have varying levels of chemical components. We know this from research experience. We know, too, that various cultural practices and curing processes affect the chemical composition of tobacco leaves. Once we have identified compounds that may be irritants to the human system, it should be possible for plant breeders to eliminate or greatly reduce various substances from tobacco plants--or for chemists to remove them by special processes.

In still another direction, our pest control research and education program is directed toward reducing the pesticide residues in man's total environment. In spite of the tremendous benefits of pesticides, we recognize problems connected with their use. Within our resources, we are making every effort to find new ways of fighting pests without hazards. To give added impetus the Congress provided a fund of $25 million for a program of research and education within USDA. This will include increased work on biological control involving parasites and predators against insects; insect pest attractants; and sterilization method of insect control, which has already achieved such brilliant success against the screwworm.

We are increasing our basic research on the biology of pests, diseases, and parasites, and the further development of genetic resistance in plants to diseases and insects. We will also be able to conduct more research on specific, less persistent pesticides and improved methods of application. Part of the special fund is being used to monitor and evaluate the effect of normal use of pesticides on the total environment, including soil, water, crops, livestock, fish, and wildlife. In all these efforts we are coordinating closely with other State and Federal agencies--especially with the Departments of Health, Education, and Welfare and Interior. Through this crash program of research and regulatory activities, we should be able to solve more of our pesticide problems--faster.

One of the changes that is affecting research in USDA is the need for increasing emphasis on the training and retraining of our scientists. With rapidly developing funds of knowledge, each individual scientific discipline and interrelationships between disciplines are becoming increasingly complex. That means that agricultural scientists must have thorough training in our schools and colleges. It also means that we must find ways to attract the better students and potential scientists to agricultural research. Too often the students with the best inquiring minds are attracted to research that seems

more glamorous. They are inclined to think of agricultural research as studies on how to feed pigs and chickens and how to fertilize plants.

These are important parts of our work. But many potential scientists don't realize the opportunities for challenging study in such fields as basic research in manipulating germ plasm and digging deeper into the character of the living cell. Agricultural scientists, working with plant and animal viruses, are dealing with the component parts of life itself, stripped down to one of its simplest forms. They are finding new explanations for plant proteins, blood antigen, and the effect of light on plant growth. In fact, the opportunity to make important contributions to world knowledge through agricultural research is almost limitless. We must find ways to attract more top scientists to these challenges.

But just hiring good, well-trained scientists is not enough. We must cope with the fact that training becomes obsolete. Borrowing a term from the atomic scientists, we can expect the college training of some scientists to have a "half life" of only 10 years. In other words, half of what the student knows about his major subject at graduation will be obsolete within 10 years. This is critical with scientists today because of the rapidity with which science is changing. It is vitally important that we provide for the continued advanced training and retraining. And we must provide the proper environment and climate in which a scientist can do his best work.

To find out how well we were meeting these needs in USDA, I asked the Secretary to set up an interdepartmental task force to study training and scientific environment of the Department's research and education personnel. This task force has been in operation since last April to evaluate and make recommendations about the following specific points:

(1) The training of USDA scientists in relation to our current research and education needs, the opportunities to improve training, and the extent to which these opportunities are used.

(2) The intellectual and scientific environment of Department scientists and the extent to which these encourage or discourage productive research and education.

(3) The extent of the Department's participation in training of agricultural scientists through intramural programs and in cooperation with universities.

This is a carefully planned and executed survey, and we are finding many significant factors involved in our scientists' training and environment. For example, the attitude and interest of agency administrators and research supervisors toward training largely determine the <u>quality</u> of training programs and the <u>participation</u> in such programs. For example: Our survey showed that training activities in one location were practically nonexistent, although the opportunities were excellent. In another, with fewer opportunities, dynamic programs were underway as a result of enthusiastic leadership and encouragement.

In general, our scientists are not well informed about the Department's policies related to training or about the use of various training authorities and mechanisms. This lack of information about such opportunities reflects lack of communication. We plan to make proposals and take steps based on the

survey. Our actions will emphasize increased professional training and broadening the background of understanding among our personnel by periodic change of assignments, within the Department and in cooperation with universities.

I believe there would be considerable merit in moving more of our scientists into university centers for brief periods. In addition to getting formal training, the scientists could bring their experience and background to bear on work at the schools. Moving a man from one State to another, with varying agricultural problems, would be certain to bring fresh ideas and concepts into any mutually conducted work. By exchanging personnel with the universities, we could increase the mutual value even further. We hope to make more use of these opportunities.

Another change within the Department which we expect will influence future programs is that dealing with coordination and planning. A new Program Development and Evaluation Staff has been set up to help me and agency heads develop and review future research programs. We call this our internal review mechanism. In our relationships with State Experiment Stations we have taken steps to improve our nation-wide planning and coordination. Secretary Freeman has established a Research Planning Committee to bring about this improvement. There are six administrators from State institutions, six from USDA and two nominated by outside organizations: the National Academy of Science and the Office of Science and Technology.

And as we look to the future, what do all these changes mean? Can we expect increasingly better work in the years ahead? The answer depends partly upon support--support from adequate research budgets, which, in turn, depends upon support from those who need and use the results of our research. But in the final analysis, the fate of our future lies in the minds and accomplishments of each individual scientist in USDA. It is only through their success that our research program can be successful.

COMPETITION AND COOPERATION IN THE PRICING OF U. S. WHEATS IN EXPORT MARKETS

Robert G. Lewis
Deputy Administrator, Agricultural Stabilization and Conservation Service, USDA, Washington, D. C.

My subject is fairly complex and involves questions for which answers have not been found. It also involves answers that are continually being questioned. Some would call this "a controversial subject." I am not interested in provoking controversy, but I do wish to look clearly at the facts and to think clearly about choices and consequences. I am indebted to my associates in the Department of Agriculture for advice and instruction in the preparation of this paper, but the judgments and policy choices are strictly my own and do not necessarily represent nor forecast the position of the Department.

First, let me review the evolution of the present world wheat price structure, in order to put our wheat pricing problem into perspective. Before

World War II, international wheat prices moved freely in response to supply and demand, without much if any government intervention. The world market was dominated by the Liverpool Exchange. The Chicago market, the Winnipeg market, and the Bolsa in Buenos Aires all reflected Liverpool values less freight. The world supply of wheat varied a great deal with weather patterns and the influence of price itself. The world demand likewise was influenced, as it is today, by such factors as international tension and by economic cycles which affected the ability of countries to pay. International prices responded with violent fluctuations of a degree unknown today. During this century the yearly average price of Manitoba No. 3 wheat in store at elevators at the upper Great Lakes ports ranged from a low of 42¢ in 1932 to a high of $2.36 per bushel in 1919 (in gold dollars). Subsequently, under the influence of World War II and prior to the International Wheat Agreement, the yearly average reached an all-time high of $2.84 per bushel in 1947, going above $3.25 in November of that year. Even though US production was predominantly consumed domestically, prices here also tended to reflect the world market. For example, average prices for wheat received by farmers in Kansas ranged from $2.14 a bushel in 1919 to 36¢ in 1932, and reached $2.25 during the peak in 1947.

The seeds of the present world marketing pattern were sown in the depression years when prices reached such low levels that many farmers were driven to bankruptcy. There was no effective government action to stabilize prices anywhere prior to creation of the Canadian Wheat Board in July 1935. Initially, this Board was a voluntary agency empowered to purchase all wheat offered by Western Canadian producers. It was not until September, 1943, under the influence of World War II, that it was given monopoly authority for marketing Western Canadian wheat, and trading in wheat futures on the Winnipeg Grain Exchange was prohibited. The Wheat Board evolved from extensive cooperative grain marketing by Canadian farmers in the 1920's, and to their demands on the government for harder-hitting action during the market collapse of the 1930's.

In the United States, various programs were undertaken also during the 1930's, after campaigns for help to producers during the 1920's. However, wheat exports were relatively much less important to the farmer's income in the USA and the depression gave rise only to small annual subsidized export programs for wheat and flour beginning in 1934. During the 12 years through 1946 these programs totaled only approximately 300 million bushels. There were no export subsidy programs from 1946 to 1949, but there were some nonsubsidized military and similar government programs between 1944 and 1949. The present subsidy program began in August, 1949, with the International Wheat Agreement.

Events in other major wheat exporting countries roughly paralleled those in Canada and the United States. The Australian government assumed all wheat marketing during World War II, and thereafter the Australian Wheat Board has served as a marketing monopoly in both domestic and export trade. In Argentina, all private grain handling facilities were expropriated in 1944, and the government became the sole operator. In the late 1950's, domestic trade was restored to private hands, and in 1960 export trade was returned to a controlled free market. The Grain Board, however, maintains guaranteed minimum prices to producers and also guarantees observance of minimum prices under the International Wheat Agreement.

International trade in wheat was thoroughly disrupted by World War II. Governments in both exporting and importing countries regarded food products as comparable to munitions and were forced to intervene in the trade. At the War's end government control was continued to cope with the physical and financial problems of feeding the populations of devastated countries in Europe and Asia. A pattern of commercial trade began to re-emerge in the late 40's, alongside continuing government-financed relief programs. In this climate of world-wide scarcity the International Wheat Agreement was negotiated in 1949 after unsuccessful attempts in 1939 and 1948.

I think the best way to understand the purposes and operations of the International Wheat Agreement is to understand the basic facts about the farm economy. The individual farmer has no bargaining power. He asks the price for what he buys, and he asks the price for what he offers to sell. Farmers have no withholding power. If a farmer takes his wheat home, he will be without income, but he will not influence the market. The farmer cannot move his productive resources into some other line. His land, machinery, buildings, and livestock are all good for one thing. Even the labor of American farmers--who are the most efficient and most productive farmers in the world--often must compete at the bottom of the economic ladder if they move into the industrial labor market.

The situation is entirely different in manufacturing. If the manufacturer doesn't get the price he wants, he locks up his inventory, lays off some workers, slows down his plant to less than full capacity, and waits until customers will pay what he thinks he ought to have. He has withholding power and is able, as economists say, to administer his resources so that he gets the price he feels he must have. This is true all over the world.

The domestic price support programs, instituted in the 30's, have helped to correct the farmers' lack of bargaining power in two major ways: First, they determine a "fair" level of return to the farmer that is deemed acceptable to the public. Public acceptance is expressed in price support legislation. Second, price support enables farmers to administer their resources somewhat like other businesses. Land diversion provisions enable farmers to withhold resources from production in order to manage the supply. The price-support loan provision enables them to withhold stocks in inventory in order to manage the supply that's put on the market. This results in an administered price at a level acceptable to the public as "fair" to farmers. It gives the farmer the same kind of pricing machinery, in a general way, that every manufacturing industry enjoys.

The International Wheat Agreement has prescribed a range of prices which has been accepted by importing and exporting countries. It is comparable with our price-support operations in that it prescribes a level which is agreed to as "fair." The countries which import sit down on one side of a table; the countries which export sit down on the other and they negotiate until they reach a price range that both consider to be fair to both producers and consumers.

It was my honor to be the Delegate of the United States in the session which produced the present Agreement. The price range was increased in this

Agreement, negotiated early in 1962, by 12-1/2 cents per bushel, from a minimum-maximum range of $1.50 to $1.90 a bushel to a range from $1.62-1/2 to $2.02-1/2. These prices relate to Manitoba No. 1 wheat in store at port warhouses in Port Arthur-Fort William at the head of the Great Lakes, and are approximately comparable to prices at the farm in central Kansas of $1.15 to $1.55 per bushel for ordinary hard red winter wheat.

The International Wheat Agreement does not have a direct surplus-holding program comparable to the important second aspect of our domestic program. But the International Wheat Agreement leans on and makes use of the surplus-holding programs of the United States and Canada--the two largest exporters. The "carryover" into harvest time has amounted to as much as 118% of a year's normal crop in the United States, and 142% in Canada.

Other countries also export significant quantities of wheat, particularly Argentina, Australia, France, Sweden, and usually the USSR. Other exporting countries--Spain, Italy, and Mexico--frequently have no exportable surplus and actually need to import wheat. Nevertheless, the United States and Canada are so preponderant in the export market that they can affect the world price by withholding surplus stocks. Despite the ability of the two countries to act by themselves, there is an important advantage in having the USA and Canadian stock-withholding policies complemented with the Wheat Agreement. First it leads to world-wide recognition that what the United States and Canada are doing, in withholding stocks from immediate sale, is in the world's public interest. USA and Canadian wheat reserves are in fact the world's insurance against famine.

The world's last great famines occurred 22 years ago, in Bengal in India and Honan Province in China. Millions died of starvation--literally starved because there was not food anywhere within reach. Into the 1940's megadeath famines--by the millions--were commonplace in the world. There have been no megadeath famines in the last 20 years, primarily because of productivity of farmers of the United States and Canada. We have maintained a reserve of wheat, and when famine threatened in Western Europe right after World War II, wheat from North America saved the lives of millions. When famine threatened many times since then in parts of Asia, Africa, and South America, our wheat has come to the rescue. Reserve supplies held by Canada have been used primarily on a basis of commercial sales. A preponderant share of our wheat reserves has been supplied on "concessional" terms, including sales for inconvertible currencies and outright gifts.

Every detail and aspect of wheat policies and programs in the United States and Canada is subject to searching examination by the International Wheat Council, comprised of delegates from member countries. This function of the International Wheat Agreement has helped the world to understand that our wheat is the world's reserve against famine, that it serves the world's interest, and is not a monopoly pricing action to jack up the price. It has helped to drive home to the people of the world the fact that current wheat prices need to take account of the cost of maintaining reserves. It insures importing countries against skyrocketing prices and scarcity in times of short crops or high demand.

It is important to recognize that the International Wheat Agreement is a "gentlemen's agreement." Exporting countries have lived up to the Agreement when world market prices exceeded its maximum, by furnishing specified quantities to member importers at the Agreement price. But the Agreement has never been put to the test in supply circumstances which would warrant application of its minimum price provisions. The reason is that it simply isn't practical to expect some 50 or so importing countries, many not well developed financially or politically, to pay cash prices above the going market price under a treaty which provides no penalties that can be made to stick. The Agreement itself has no teeth by which its provisions can be forced upon member nations. The withholding power of the United States and Canada, exercised outside the Agreement but within its full view and approbation, actually "enforces" the minimum price policies written into the Agreement. Supplies available from our own and Canadian reserves insure supplies for importing countries at prices within the range in case of short crops.

I have described a novel mixture of a multilateral treaty, national economic policies and administrative practices, voluntary national discipline, international good will and good faith, tolerance and patience toward small and weak countries, and some sense of common interest in man's fate. The components are loosely and even informally knitted together, but they comprise a world wheat price and supply stabilization program of sorts. World wheat prices are 25 to 30 cents per bushel higher today than they probably would be under similar circumstances if this unusual apparatus did not exist. On the other hand, wheat has been sold under the Agreement during periods of scarcity at prices about the same amount below the going market price for wheat traded outside the Agreement.

There are however many inefficiencies in this loosely knit stabilization system. The most important is lack of participation by other wheat and flour exporters--particularly Australia, Argentina, and France--in the voluntary stocks-withholding and price-strengthening efforts of the United States and Canada. These other exporters at present do not withhold "surplus" stocks in the interest of stabilizing prices. Their policy is to undersell wheat from the United States and Canada, so as to clear out each year's production by the time a new crop comes along. They are sheltered by the umbrella held by the United States and Canada, but they do not contribute to its support.

Production and sales have varied irregularly in the exporting countries since 1950. Australian harvested acreage increased 40% while our harvested acreage dropped 20%. Canadian acreage increased 8%, while Argentina's, after dropping to little more than one-half, recovered in 1963 to the same point as in 1950. During the past 10 years, country shares of the world's total commercial wheat market (excluding Communist countries) have changed as follows:

Comparison of 5 years (1953-54/1957-58) with 5 years (1958-59/1962-63)

		Percent
United States	Up from	17.2 to 20.3
Canada	Down from	34.6 to 31.4
Argentina	Down from	13.5 to 9.5
Australia	Up from	11.7 to 14.0

France hopes to expand its grain output and its share of the total commercial wheat market through trading advantages within the EEC.

The abundant supplies and lagging export demand this year, contrasting with 1963's strong demand and huge export sales, has focused sharp attention from the trade, producers, and government administrators in the United States on this inadequacy in the present world system. The reflex-action response of many is to urge an increase in the United States export subsidy, thus slashing the net export price of our wheat in order to "compete more aggressively." But no more than a second thought is needed to perceive the dangers of this prescription. Other exporting countries can and probably would reduce their prices accordingly, and the unsatisfactory relationship would go on but at a lower level of prices. The price-supporting functions of the international system would go overboard; the baby would go out with the bath.

As often happens, the prescription of what seems to be a "cure that would kill" has deeper purposes. Deliberate abandonment of international efforts to stabilize prices is one of the alternatives that some propose to discourage increase in production by countries which do not now cooperate in holding surplus stocks off the market. Those who advocate this alternative suggest that the United States, through its export subsidy operations, should make our wheat available at prices so low that unsold stocks would be backed up in other exporting countries, thus forcing high-cost producers out of business and preventing further expansion of production. This proposed approach is familiar to students of domestic farm policy discussions during the 1950's.

Although in the short run a world wheat "price war" would be questionable in expanding our market for wheat, it might well result in restraint upon production in the longer run. To the extent that our producers could outlast those of other countries at low prices, or could retain the assistance of subsidies from our government, our share of the world commercial wheat market could be enlarged. However, this approach entails five serious disadvantages that make it seem to me the less attractive course of those open to us:

1. Wheat prices received by USA farmers probably would be reduced quickly as world price went down. To maintain domestic prices at levels above the world market, export subsidy is required from the government. It is not likely that our political authorities would accept an overall increase in cost of subsidizing exports of wheat. Therefore, declining world prices would be reflected quickly in losses in prices received by our farmers.

2. A sharp decline in wheat export earnings would inflict hardship upon strategically vital allies and trading partners of the United States, particularly Canada, but also Australia and Argentina. The cost of a sharp cut in world wheat prices might be considerable in terms of strategic, military, economic, and political support for our goals in world policy. Incidentally, such a decline in export income of Canada probably would result in loss to the United States of more agricultural export business than it would gain, for Canada is our second-largest customer for farm exports, and wheat is its major earner of foreign exchange.

3. Both consumers and producers in the largest commercial wheat market in the world would be insulated from effects of reduced world wheat prices. The "variable levy" in the new European Economic Community trading system would maintain costs of imported wheat to EEC consumers at the high EEC domestic level

and would "skim off" the difference for use by EEC governments for their farm subsidies and export assistance operations. Thus, reduced world wheat prices would have no value in enlarging consumer demand for USA wheat in this market, and in fact would help to finance incentives to production by European farmers.

4. Reduced world prices for wheat would cut our export earnings and adversely affect our balance of payments almost in direct proportion to the amount of the price reduction. It is improbable that our share of the world export market would be greater at lower wheat prices, at least not until production cutbacks had been forced in other countries at a greater rate than in the USA.

5. World population is increasing at an unprecedented and still-accelerating rate; and world output of agricultural products needs to be increased sharply, rather than decreased. A large proportion of the population is seriously undernourished, and total world food output is not now keeping pace with increase in population. Farm price levels, particularly in less-developed countries with exploding population growth, need to be stronger rather than weaker to attract into farming the capital and other resources needed to produce adequate food. By itself, production of food is not enough to insure that hungry population will be fed. Efforts and innovations of as-yet-undefined proportions will be needed to finance and distribute supplies where food is needed. But there can be no doubt that in anything beyond the very short run, an enormous effort is called for in both food-exporting and food-deficit countries to expand world supplies at a rate that staggers the imagination.

Today's loosely knit system of stabilizing world wheat prices will probably need to be strengthened and improved if it is to survive for long. There is growing impatience in the United States with the extent of the burden imposed upon our producers for acreage reductions, and upon our government for surplus utilization and control programs, without commensurate sacrifices by other exporting countries. Some of the most serious shortcomings could be substantially overcome by the following steps:

1. Establishment by at least Australia and Argentina of policies of holding stocks of grain comparable to those of the United States and Canada. Any such undertaking by these countries would be modest in comparison with the operations of both the USA and Canada, but programs of feasible scale can probably be devised. A rational argument can be made to those countries that they can come out ahead in terms of total revenue from sales of wheat under a rationalized marketing operation, even if the total volume sold is somewhat smaller than would be possible in the short run under "price war" competition.

2. Securing for grain exporters equitable terms of trade with the EEC. The central objective in negotiating terms with the EEC must be access to the EEC market, and guaranteed sharing in the market growth for efficient producing countries.

3. Securing more equitable participation by grain-exporting countries, and by prosperous importing countries as well, in the costs of economic development, including provision of food aid to meet deficits in supplies provided through commercial channels. Whether aid for economic development is furnished in the form of foods or otherwise, the food-deficit and underdeveloped countries are the logical and necessary outlet for food supplies that are "surplus" to commercial requirements.

In the meantime, the Department of Agriculture's responsibility continues. It is charged with operating an export subsidy program which will keep US wheat "competitive" in world markets. Webster defines competition as "the effort of two or more parties, acting independently, to secure the custom of a third party by offering most favorable terms." The orthodox interpretation of the term "competition" clearly implies price competition, reflecting supply, effective demand, and costs of the most efficient producer. The plain fact, as we have seen, is that international wheat trade is not price competitive in the orthodox sense. Rather, it is a classic example of an oligopoly, one operating under public control and with the tacit public sanction of the countries concerned.

The export pricing of our wheat is accomplished through the subsidy program. Compelled on the one hand to exercise that measure of restraint which will preserve the world price structure, we are committed on the other to be as aggressively competitive as we can. Obviously, success depends primarily upon the accommodation achieved with other exporters. The United States and Canada are the principal competitors in the pricing of wheat in world markets. Both recognize that the two countries are the only exporters that have the ability or policy of withholding stocks beyond the current year in the interest of maintaining prices. Thus, the price level they establish becomes the standard for world prices. Pricing is carried out independently in each country. However, it is in the interest of both to hold prices above the stock-clearing level, and both conduct their stock-holding and pricing policies so as to "support" the world price.

This similarity in policies results in a particularly acute competitive relationship between suppliers of United States and Canadian wheat. Both countries have a strong interest, on the one hand, in maintaining their best possible share of total world trade. On the other hand, both have a strong interest in maintaining prices at levels remunerative to farmers in Canada, and at levels which minimize program costs and thereby improve the climate for supported prices to farmers in the United States. A wheat "price war" would be detrimental to the interests of both, yet each must be prepared to accept even that eventuality rather than to allow its appropriate share of the commercial market to be eroded. Each therefore seeks to price its wheats at levels that maximize its marketings without provoking a retaliatory cut in price by its competitor.

Under these circumstances, price as a competitive tool is severely blunted. Almost any other factor is more feasible and easier to maintain. Quality is the major nonprice competitive factor in world wheat trade. Unfortunately, United States wheat historically has labored under a quality disadvantage as compared to other major exporting countries. Until recent years, production in USA has been geared principally to domestic requirements. Our intricate marketing system developed in response to domestic demand during a long period when exports were secondary. The result has been movement through country elevators, subterminals, and interior terminals which enable domestic processors to pick over almost the entire supply and select that portion having the most desirable milling and baking qualities. In other principal exporting countries domestic demand has much less consequence, and wheat moves directly from production areas to ports to be marketed on a "fair average quality" basis.

United States producers gain from the higher premiums that domestic processors pay above world market, but our marketing pattern puts our wheat at a distinct quality disadvantage in export markets.

During recent years, exports have supplied an increasingly important outlet for United States wheat. During the current year, as for the past three, more of our wheat is being exported than we are consuming. Our system, including price-support rate patterns, must be adapted to this circumstance as quickly as possible. Moreover our marketing, production, and pricing policies must take realistic account of the fact that a major portion of our export volume goes to countries that do not have the same quality concepts as other buyers who use wheat for bread.

Perhaps quality offers the greatest potential for improvement in our international competitive position--given the world price structure with which we are confronted. For the moment, the quality problem is serious. But progress is being made. The recent modification of our grain standards should improve the acceptance of our wheat when buyers become more familiar with it. The wheat promotion and advertising work being done abroad is a help. However, much more needs to be done to establish positive quality controls on the part of merchandisers, so that they can sell United States wheat meeting exacting specifications as dependably as "fair average quality" wheats from other sources. Our producers, whose interest in maximizing sales of their own wheat is not diluted by concurrent interests in selling wheat from other origins, may need to take a stronger and more direct hand in the export business.

Another major competitive factor is service. We are blessed with an abundance of all-season, deep-water ports on two oceans, port elevator facilities second to none, an adequate internal transportation system, and the world's finest financial and communication facilities. In general, the United States has a decided advantage in service. But there are exceptions. Certain qualities of our wheat cannot be made fully competitive at the proper port of export, usually because of freight-cost disadvantage. We have experienced extreme difficulty in supplying hard wheat to Japan through West Coast ports. We have not capitalized fully on demand for exceptionally high spring wheat proteins which are wanted in certain markets and are not readily available from any other exporting country. And we have a persistent problem in keeping our bread wheats competitive with Canadian wheats shipped from Vancouver in certain markets where ocean freights favor West Coast shipment.

These problems all can be traced to differences in internal freight rates between our northwestern states and the adjacent production area in Canada. Canada has a national policy of subsidy for movement of wheat on railroads, whereas we do not. Under the Crow's Nest Pass Agreement, rates on movement of Canadian wheat from the Prairie Provinces to Vancouver are only about one-fourth the rate for comparable movement from our spring wheat production areas to Pacific Northwest ports. The Department is cooperating with trade and producer groups to secure rail freight reductions to enable exporters to continue to supply these markets.

This account would not be complete without noting that our wheat is barred from markets that account for all of the gains in total exports scored by our

competitors during the current season. Our wheat is barred not by competition but by national policies. Trade with Red China--recently a major new factor--is banned outright. Sales of grain to the USSR and Eastern Europe are unfeasible because it must be shipped in part in USA-flag vessels at costs higher than cost from competing sources. Our wheat will not be sold in these markets so long as supplies can be obtained elsewhere.

Now to summarize briefly and offer some conclusions. I have pointed out the extent of the loosely knit world wheat price stabilization efforts in which we and others cooperate, and their importance to our farmers. Unquestionably these efforts, of which the International Wheat Agreement is a central part, are instrumental in maintaining world prices about 25 or 30 cents above the level we otherwise could expect. From what I know about political, economic, and fiscal pressures within our government--regardless of party in power--I am convinced that if the world price of wheat should be brought down, soon afterwards every cent it falls would be taken off the price that our farmers get for wheat. In the interest of our wheat farmers, prompt action should be taken to correct the shortcomings and strengthen the structure of the international wheat stabilization effort.

I have pointed out that it is important that our wheat compete aggressively in world markets, within the framework of international stabilization of prices. Our wheat must be priced realistically, so that it commands its full share of the world market. Exporters of our wheat must provide dependable quality, under acceptable terms and circumstances, so that buyers will come back for more. Much more should be done, particularly on competitive factors other than price, to improve the acceptability of our wheat in world trade.

The necessity for both approaches is fairly well recognized by all concerned in the wheat trade. However, this moment in history affords us an opportunity to score a dramatic breakthrough in expanding the sales of our wheat, which is little appreciated. That opportunity is based on economic development in heavily populated low-income countries. It depends upon creation of effective buying power among half of the world's people, who are now undernourished. There are large potential markets for our farm products in the emerging friendly countries of Latin America, Asia, and Africa. Wheat--to provide the staff of Life--is usually first and foremost among products those countries will buy as soon as their economies begin to grow and their incomes rise.

We find that we export about $1.00 worth of farm products from the United States for each $100 of average per capita annual income in both the developed and less developed countries of the world. When their annual income goes up $100, our farm exports go up about $1.00. Nearly one and a half billion people live in countries that are near the bare bottom in per capita income. If these countries were able to increase their incomes by only $100 per person per year, they might import more than $3 billion of agricultural products from the United States each year, about double our present exports. And wheat will be among the first and foremost products to benefit from such expansion.

Nothing that wheat farmers or governments can do to support wheat prices, to compete for wheat markets, or to advertise and promote consumption of wheat

can begin to compare with the boundless opportunity for market expansion that could be achieved by raising the standard of living in the underdeveloped countries.

Our government for many years has made strenuous efforts to promote economic development and higher standards of living. This effort has included direct financial assistance and aid under the Food for Peace Program. But aid can never be more than a drop in the bucket; it can only prime the pump of progress. Significant purchasing power can be achieved by these people only in the same way that we achieve it--by selling goods and services to those who have goods and services to exchange. Our purchases of products which they produce undergird the transactions that started and grew in the course of our aid programs and furnish the only real promise for genuine markets for our commodities.

For every dollar we paid to Brazil last year for coffee, about 21 cents found its way directly into the pockets of our wheat producers. We spent $393 million in Brazil for coffee, and Brazil imported $81 million worth of our wheat. Of every housewife's dollar spent for cane sugar in Peru last year, about 13 cents was spent here to buy wheat and flour for Peru. Peru shipped us $51 million worth of sugar and imported $6.5 million worth of our wheat and flour. For every American dollar paid to Nigeria for cocoa, 30 cents was spent for wheat from the United States. Nigeria exported $15 million worth of cocoa to us, and imported $4.8 million worth of our wheat. Of course, people in these countries buy many other things from the United States. But imports of wheat absorb a sizable share of the total earnings from these tropical commodities.

Expanded trade with countries having huge and hungry populations is in the immediate and positive interest of American wheat farmers more particularly than any other group in our economy. Unlike more prosperous countries, a substantial fraction of every additional dollar is earned in these countries will be spent on the necessities of life, outstanding among which is bread.

It is appropriate, therefore, that producers of several tropical agricultural products have turned to the experience of the world's wheat producers for a model in international cooperation to stabilize prices and marketing. International commodity agreements for sugar, coffee, and cocoa are in various stages of discussion, negotiation, and implementation. Their purpose is to strengthen and stabilize prices, even as the purpose of the international wheat program protects the wheat producers. International commodity agreements are a major feature of world cooperation to boost living standards of low-income countries.

Wheat producers are close in line--after the primary producers themselves--for the benefits that will flow out of economic progress thus generated. The wheat farmers of the United States can probably get more done to increase sales by lobbying in Washington for approval of the International Coffee Agreement, which would underwrite and strengthen the purchasing power of hungry new customers for bread in Latin America and Africa, than by any amount of more conventional advertising and market promotion efforts they might undertake. And so we come full circle, to a renewed appreciation of the central place occupied by wheat in the affairs and destiny of Man.

The technique of international cooperation that has achieved stability for producers of wheat and consumers of bread during 15 years now promises help to assure rising earning and buying power. That power converts want into market demand and hunger into consumption, without which the farmer's ancient mission to feed the hungry cannot be fulfilled.

THE ECONOMICS OF A LOAF OF BREAD: FROM THE FARM TO THE CONSUMER

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> It is said that a dollar a day is not enough for a wife and five children. . . . But is not a dollar a day enough to buy bread with? Water costs nothing; and a man who cannot live on bread is not fit to live. (From a statement by Henry Ward Beecher directed at railroad employees striking against drastic wage cuts in 1887; cited by Henry F. May, Protestant Churches in Industrial America, 1949, p. 94.)

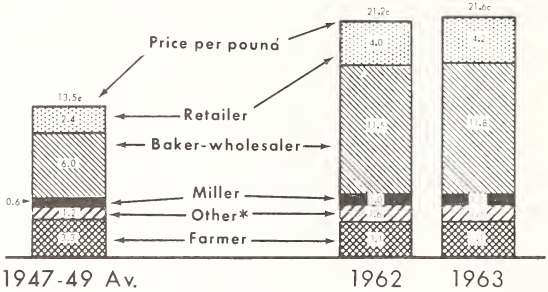
The economics of a loaf of bread is a subject that dates back to earliest history. Throughout this history, the questions have been those raised in this quotation of 1887. Unfortunately, these are still prime concerns of much of the world. We are privileged that we can concern ourselves with the economic issues that embrace and envelop a loaf of bread in the United States in 1964. ("Two-thirds of the world's people live in countries with nutritionally inadequate national average diets," The World Food Budget 1970, Foreign Agricultural Economic Report No. 19, Econ. Res. Serv., U. S. Dept. Agr., October 1964, p. iii.)

The economics of a loaf of bread encompasses an intricate and complex set of operations. Consider those in the production not only of wheat but the other ingredients in a loaf. Then add other activities in transportation, storage, milling, baking, distribution, and retailing, together with the industries of packaging and other supplies, utilities, the fertilizer and chemical industries, research, and government. Then consider the contrast with a subsistence economy where production of grain and grain products for comsumption is performed in each household.

It is indeed difficult to comprehend the specialization and array of individual jobs and services that are represented in an "ordinary" loaf of bread. We depend upon a competitive enterprise economy to coordinate, through price determination in a multitude of open markets and contracts, the performance of these tasks. We also depend upon this economy to provide remuneration to all who assure the continued availability of these services. It is not surprising that in an economy such as ours, where change is its most outstanding characteristic, controversial, complex economic issues are involved in the "ordinary" loaf of bread.

Who gets what and why? First, let's look at the price of a loaf of bread. Figure 1 tells us that the US consumer paid an average of 21.6 cents for a

1-pound loaf in 1963. Further, it tells us that of the consumer's 21.6 cents, the baker-wholesaler got 11.8 cents, about 55%. The retailer got just under 20%, 4.2 cents. An estimated 3.1 cents, or 14%, got back to the farmer. This includes the dairy farmer and the sugar-beet producer as well as the wheat farmer. The flour miller's share was 1.0 cent, less than 5%. A residual of 1.5 cents is divided among elevators, transporters, processors of nonflour ingredients, and other marketing agencies.



*OTHER HANDLERS AND PROCESSORS

Figure 1. Consumer's bread price.

This statistical picture has limitations, one of which is its static nature. Figure 1 also shows the change in the retail price of a pound loaf of bread since 1947-49 and the changes in distribution of retail price among the four principal claimants--retailers, bakers, millers, and farmers. The most significant statistic is the rise in price from 13.5 cents in 1947-49 to 21.6 in 1963, an increase of 60%. This compares with an overall average increase of only 15% in retail price of all farm food products. The post-war rise in the price of bread has far outstripped that of any other major food product. (Based on data for the retail-store cost of a market basket of farm-food products, published quarterly in Marketing and Transportation Situation, Econ. Res. Serv., U. S. Dept. Agr.)

Also significant is the distribution of price increase among major claimants. About 70% of the 8.1 cent rise went to the baker-wholesaler--the baker's share increased from 44 to 55%. The return to the farmer declined by 0.2 cent, and his share from 24 to 14%. These are relevant statistics, but let me caution you against an "obvious" conclusion that bakers are "lining their pockets" at the expense of farmers and consumers. Figure 2 casts considerable doubt on this conclusion. Profits of six major baking companies as a part of the sales dollar were lower in 1963, not higher, than in 1947-49.

To get more meaningful answers, we must probe deeper and ask the following questions: (1) What are the changes in the services performed? And I include all services--production of raw materials, processing, transporting,

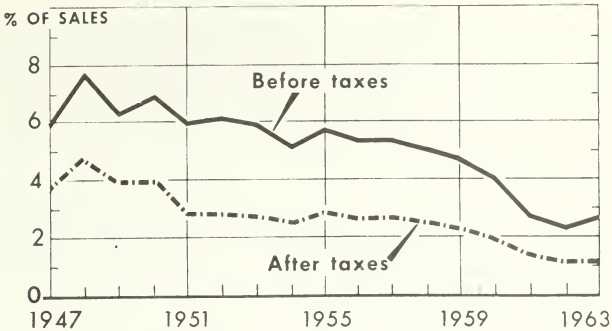


Figure 2. Profits of six major baking companies.

storage and distribution--giving so-called marketing or distribution services no lower ranking than so-called productive services. (2) What are the changes in costs of the resources used, such as labor, packaging supplies, fertilizers, and insecticides? And (3) what are the changes in the efficiency with which these resources are used, i.e., their productivity?

Again, various statistics are relevant even if they do not provide all of the answers. Labor productivity in baking has lagged notably in comparison with most other industries. During the period 1947-58 it rose only 18%, the lowest among major food industries. (William H. Waldorf, Output Per Man-Hour of Factories Processing Farm Food Products, Technical Bulletin 1243, U. S. Dept. Agr., May 1961, pp. 11-13.) In contrast, in the same period, production of food grains increased by 10%, while the estimated man-hours used for farm work in the production of these grains dropped by 55%. In production per man-hour, these statistics represent an increase of two and a half times in an 11-year period. (Changes in Farm Production and Efficiency, Statistical Bulletin No. 233, U. S. Dept. Agr., July 1964, pp. 7-8, 35.)

These numbers suggest that rising costs of resource-inputs and relatively low productivity gains in baking have been reflected in higher gross margins to bakers and a higher share of the retail price. Farmers also have faced sharp increases in prices of their inputs. However, unlike the bakers, the phenomenal gains in productivity in agriculture have helped farmers offset the double impact of higher costs and lower prices. But neither the bakers nor the farmers have profit positions that would be envied by many other industry groups in our economy.

The fifth party. Thus far, I have referred to four major parties in the economics of the price of a loaf of bread. Now let me bring a fifth party--the consumer. In 1887, the Reverend Mr. Beecher could take the dollar-a-day family as a passive force to be molded into the requirements of a production-oriented economy. Not so today. As the wheat-to-bread industry well knows, the problem today is not one of production, but one of markets. The consumer

has the major decision-making role in determining how large a market you have; your production no longer determines how full his stomach will be. Alternatives among foods as well as nonfoods are increasing. A rising number of consumers have the incomes to give them more power to decide how much shall go to food and how they will spend the food dollar. In 1963, 20% of our families had incomes of $10,000 and over, compared with 3% in 1950; more than half had incomes over $6,000; in 1950, only one family in seven had more than $6,000. (Bureau of the Census: Incomes not adjusted for changes in the price level between 1950 and 1963.)

How does this more affluent consumer make his choice? Price, quality, convenience are all important, but how important is each of these to groups of different incomes, family composition, ethnic backgrounds, occupational groups, etc.? Psychological factors may be more important than economic. A recent article in Printer's Ink Magazine states that a baking company has learned through research that women have become bored with bread. This company decided to introduce frozen, prerisen French- and Vienna-type breads to stimulate the interest of women shoppers in bread. (Printer's Ink Magazine, Vol. 288, No.13, September 25, 1964, p. 19.)

Regional variations in flour and bread consumption suggest that factors other than price and income affect consumer decisions. Consumption of flour and bread by urban consumers in the West is about equal to that in the South and well above that in the Northeast, even though prices and incomes would suggest otherwise. (Based on data from the 1955 Household Food Consumption Survey, U. S. Dept. Agr.) Economic analysis has shown that as prices go up, consumers buy less bread. Consumers with higher incomes generally buy less bread. Yet prices and incomes are as high as, or higher, in the West than in any other region, especially the South.

I wish to emphasize that more attention needs to be directed towards the consumer. The challenge for the wheat-to-bread industry is to provide products and services that achieve maximum responsiveness to the consumers' changing needs and preferences. Much study and research is needed. I suggest that it may be more profitable to concentrate on changing the alternatives offered consumers, rather than to attempt to "alter" the consumer through advertising and promotion. Today's consumers, I believe, are not only more affluent but more knowledgeable and sophisticated in the marketplace.

Choice in the marketplace. I have stressed the importance of the consumer's ability to choose among alternatives. Ability to choose also is open to the retailer, who is assuming an increasing role in our marketing and production. First, the retailer is interested in selling bread only if the consumer wants to buy it and if it adds to his gross return. Thus the retailer's interest in the economics of a loaf of bread involves cost of the bread to him, price for which he can sell it, and volume he can sell. More and more retailers are choosing to operate their own bakeries, not because they want to become bread bakers but because they can produce and distribute at a lower cost than they can buy bread from wholesale bakeries.

Another dimension of choice open to the retailer is the markup, or his gross return. He has more flexibility than the wholesale baker, the flour

miller, or the wheat farmer. In part, this is because bread and other bakery products are a small part of the 6,000 or more items stocked by the typical modern supermarket. The retailer's net profits are the difference between his overall gross profits on all sales minus total costs. The retailer aims at a net profit on his overall operation, not on each individual product. Furthermore, most of his costs are not directly related to costs of handling individual items.

At last year's conference, I pointed out that it is easy to attach too much significance to our average retail price of bread because of variation in prices among cities and among stores in a city. The widest difference in average city prices was that between Houston and Los Angeles. In December 1963, the average price for 1 pound of white bread as reported by the Bureau of Labor Statistics was 17.6 cents in Houston and 28.6 cents in Los Angeles--a difference of 11.0 cents (Fig. 3). We studied some of the factors underlying these differences and turned up some interesting and significant facts about choices in the market (Table 1).

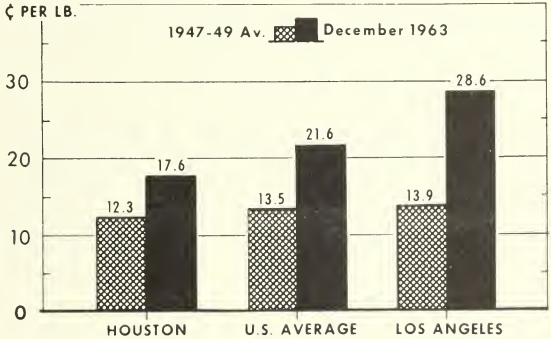


Figure 3. Retail price of white bread.

For its consumer price index, the BLS collects prices for the loaf of bread that is the predominant seller in each sample store. In most Los Angeles stores, this is the 15-ounce expanded loaf--commonly referred to in that market as the "balloon loaf". This type is not sold in Houston, where the predominant seller in all stores from which prices are collected is the standard 24-ounce loaf. The standard 22.5-ounce loaf is the predominant seller in some BLS sample stores in Los Angeles. When we compare the price of the 24-ounce loaf in Houston with the price for the standard 22.5-ounce loaf in Los Angeles, the difference between the two markets for 1 pound of standard bread is reduced to 6.2 cents. Thus, almost 5 cents of the reported price difference between the two markets is related to the popularity of the "balloon loaf" in Los Angeles.

These data raise several questions. From the consumer's standpoint, why are majority of Los Angeles shoppers apparently willing to pay a high price on a weight basis for the expanded-type loaf? Is the price per slice, which is

lower for the expanded type loaf, more important, or is there another explanation? And what is the significance of these choices in their effect on the total market for wheat and bread?

Table 1.--Retail prices equivalent to 1 pound of white bread, December 1963 (based on prices tabulated by the Bureau of Labor Statistics)

Type of loaf	Houston			Los Angeles		
	Store brands	Independent baker brands	Average	Store brands	Independent baker brands	Average
	Cents	Cents	Cents	Cents	Cents	Cents
15 ounce (expanded)	1/	1/	1/	26.7	30.6	29.7
22½ - 24 ounce (standard)	16.7	18.1	17.6	22.0	24.9	23.8
Average	16.7	18.1	17.6	25.3	29.5	28.6

1/ This type loaf not sold in Houston. Standard 15-ounce loaf is sold in Los Angeles and standard 16-ounce loaf in Houston, but these are not the predominant seller in any of the stores. Therefore, they are not reported by BLS.

We looked for explanations of the difference of 6.2 cents in average prices of the "standard" loaf of bread in Houston and Los Angeles. Lower ingredient costs, lower wage rates, and lower fixed costs of plant and equipment due to a longer work week in Houston may explain part of this difference. The impact of these higher costs on production costs of model plants of 2,000 to 8,000 oven capacity (pounds per hour) is shown in Figure 4. The average difference is about 2 cents on a pound basis. Note also from the chart the effect of a larger production on average costs per unit. (These costs are based on model

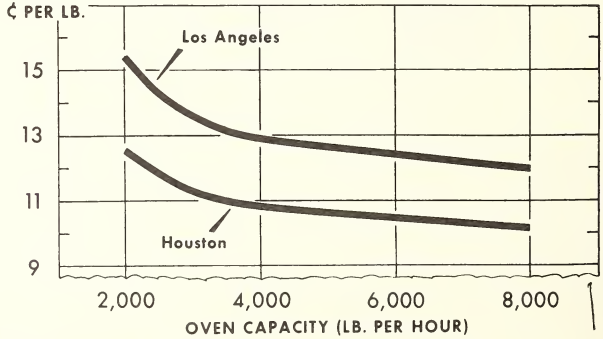


Figure 4. Estimated production costs of large loaves of standard white bread Los Angeles and Houston, 1963

bread plants with standard equipment, capacity rates of 8,000 pounds of bread per hour, operating 2 shifts for 5 days per week in Los Angeles, 6 days in Houston, and distributing by the driver-salesman. Richard G. Walsh and Bert M. Evans, Economics of Change in Market Structure, Conduct, and Performance, the Baking Industry, 1947-1958, No. 28 (n.s.), Univ. Nebr. Studies, Lincoln, Dec. 1963, pp. 143-49.)

Distribution costs were estimated to be at least 2 cents per pound higher in Los Angeles. The gross retail margin on the standard loaf apparently was 2 to 3 cents higher in Los Angeles. A part of this difference may be related to higher operating costs, but it is not possible, as noted earlier, to estimate retail costs accurately for individual items.

Needed: more research and better statistics. Now, I would like to summarize by first going back to Figure 1 and consider the significance of these and other statistics. The year 1964 has seen more discussion of prices of bread in relation to prices of flour and wheat than perhaps any other year in history. It is important from the farmer's standpoint, it seems to me, that the cost of wheat is a small part of the price of bread. The long-term, continuing rise in the price of bread since 1947 cannot be attributed to increases in the price of wheat, because the price of wheat, including the cost of the certificate, is now less than in 1947. However, changes in the price of wheat usually are closely related to changes in the price of flour, since cost of wheat generally makes up 75% or more of the price of flour. The price of flour is in turn significant to the baker, but upward trends in other costs have over-shadowed the price of flour in the post-war period. The cost of flour is therefore a declining part of the price of bread.

The farmer's share of the retail price is small and has been declining. But the important issue to the wheat producer is not the percentage he gets of the retail price of bread. His interest is in total return he can get for his product--bushels per acre times price, less total costs.

The miller's take from the loaf is a small one, and thus large percentage changes in his gross margin have small impact on retail price. But, as with the farmer, the important economic question to the miller is his net return, not his share. The miller's primary function is of course to convert wheat to flour. In addition, he provides a link in the process of communication from consumer to farmer, especially in signaling to the farmer the wheat qualities most desired in various flour uses. Unless the producer gets a clear price signal to the contrary, each producer will grow the wheat that gives him the greatest yield, even though this may not be the desired variety for flour and bread production. Now let us look again at that largest slab of our economic loaf--the baker-wholesaler. The opportunities for lowering the price of bread or preventing further increases may be greatest here.

Our Division cooperated with the University of Nebraska in an extensive study, Economics of Change in Market Structure, Conduct, and Performance, the Baking Industry, 1947-58 (cited above). There are important implications all through this report of the possibilities for lowering costs of both production and distribution of bread. These economies are often associated with the size of plant and system of store delivery. The Nebraska economists specified

alternatives, but industry executives and others will decide on the feasibility and timing of the adoption of all of them.

Perhaps the principal pressure on the baking industry to change has centered on distribution operations, primarily because chain bakeries have demonstrated they can distribute their product at less cost. A research project now underway in our Division centers on an analysis of the relative efficiencies of the driver-salesman and drop-delivery methods. Preliminary results indicate that the major cost factor under both is volume per delivery. For our sample, the volume of bread per delivery for chainstore bakeries (drop-delivery) varied from 124 to 1,800 units. The average was 1,039. The volume per delivery for the wholesale baker (driver-salesman method) varied from 0 to 280 units. The average was 30, less than 3% of the average for chainstore bakeries. All of the chainstore deliveries were made to supermarkets. The wholesale baker delivered to restaurants, mom-and-pop stores, superettes, and supermarkets. Even in deliveries to supermarkets, the average volume per delivery was only 64 units.

Thus, the important question for the wholesale baker in his efforts to reduce cost may be not what delivery method to use, but how to increase volume per stop. Furthermore, as retail stores continue to grow in size and power, the question of delivery method may be decided increasingly by the retail outlet and not left to the wholesale baker. Recently, another factor was injected into the picture. A contract was signed in southern California between representatives of 100 retail outlets and the Retail Clerks Union. (Reported in the San Francisco Chronicle, June 19, 1964.) The contract stipulated that the retail clerks have exclusive rights in shelving merchandise sold. This contract in effect kicks the driver-salesman out of the store, and most of the advantages to the wholesale baker follow the salesman. If this contract becomes a general agreement between stores and clerks, the wholesale baker may be forced to alter his distribution methods.

The Marketing Economics Division has just published a report which describes current uses of freezing by bakers, its effect on costs and sales and its prospects. (Norman L. Rollag and Robert V. Enochian, The Freezing of Commercial Bakery Products: Current Practices, Problems, and Prospects, Marketing Research Report No. 674, Econ. Res. Serv., U. S. Dept. Agr., September 1964.) Last year, I gave this conference highlights. We concluded that use of freezing by bakers will continue to increase and will be accompanied by significant changes in the organization of the baking industry. Freezing is one of the developments that are continually changing availability patterns of food and thus the eating habits of consumers. Freezing has made it possible for consumers to get fresher quality in bakery products and also to get products that could not be shipped great distances before except at great cost by air express. San Francisco's famous French breads, for example, are now shipped frozen to various parts of the country and the world.

We have just started an analysis of potentials for frozen dough. We think that such studies can help individual bakers achieve a better understanding of the applicability of freezing and thereby speed its adoption where its application can result in advantages to the baker.

As noted by a speaker from our Division at a baking industry conference last year, the problem of distribution costs in the baking industry is only a smaller aspect of a much broader problem--"producing and selling more goods and new quality products that the American consumer wants." (Nicholas M. Thuroczy, "Is Distribution the Major Problem in the Wholesale Baking Industry?" Econ. Res. Serv., U.S. Dept. Agr., Baking Industry Conference, Harriman, New York, November 18, 1963.) A well known management consultant firm has concluded that new products are basic to industrial growth and survival--today more than ever before (Management of New Products, Booz, Allen & Hamilton, Inc., 1963). To develop and successfully market new quality products will require increased research and cooperation from all parties involved in the economics of a loaf of bread.

Some concluding remarks about statistics--their importance and their limitations. I have used a great many that come from research totaling several man-years of work. These are not accurate in the sense that we think they are final and cannot or should not be challenged. They represent only the best estimates we have. Recently, our Division reprinted its publication on spreads in prices of white bread. In addition to updating the statistics, we made some changes in terminology that we hope will clear up some misunderstandings. (Spreads in Farm-Retail Prices of White Bread, Miscellaneous Publication No. 969, U.S. Dept. Agr., September 1964. It supersedes Marketing Margins for White Bread, Miscellaneous Publication 712, revised November 1962.)

We are continuing our review of the methodology and sources of statistics used to compute these spreads. As new and better data become available, we will revise our statistics. For example, a drop in the level of average retail prices of bread as reported by the Bureau of Labor Statistics is forthcoming because of recent updating that BLS has made in revising weights given foods, their sample of towns and cities, and the sample of stores in each city. In recognition of the growing importance of chains and large independent supermarkets, greater weight will be given these stores and their store-brand bread with its lower prices (see Table 1 for Houston and Los Angeles).

We have been greatly encouraged by the discussions we have had in the last year with industry representatives about our statistics. We can improve and keep our statistics up to date only by getting data from industry on changing methods and practices. I firmly believe that only through continuing industry-Government cooperation can we develop the better statistics needed in today's complex economy. Change is characteristic of this economy. Change is a built-in generator of questions and problems.

PEELING GRAIN

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A new white, unmilled cereal can be produced from parboiled wheat and several other grains by chemical peeling. The product retains all the endosperm, including the nutritious aleurone layer, but loses most or all of the colored bran layers. The bran is loosened by strong warm lye, and then removed

by vigorous water washing. Warm dilute acid restores the surface whiteness. The grain is dried in warm air. A continuous automatic pilot plant is now in operation at Albany, California.

WURLD wheat. To provide an attractive new wheat food primarily for sale in America and Europe, as well as for use in the developing countries, the wheat is parboiled by a mild version of the bulgur process before peeling. This product has been called WURLD wheat because it is a development of the Western utilization research laboratory of USDA in Albany, California. The name also suggests world wheat, because it is capable of supplying food values to the entire world. It further suggests whirled, that is, removal of bran by whirling in a water stream. Wheat peeled without previous parboiling retains a stripe of bran in the creases of the kernel. WURLD wheat is completely free of crease bran. It has a slightly yellowish cast, compared with the creamy-white color of unparboiled peeled wheat. This color diminishes on cooking because it is mainly due to the glassy transparent nature of parboiled grain. The WURLD wheat can be steamed in only 15 minutes to a white, firm food. Some of the kernels partially open out during cooking.

Peeled wheat. Another purpose of peeling wheat is to provide a raw, nutritious, white grain retaining its normal shape, probably also for use in the developing countries of the world. Wheat peeled with only mild heating (not parboiled) is rather shiny with a thin brown stripe of bran in the crease. This product can conveniently be steamed in about 25 minutes to a firm, white, free-flowing edible grain, free of surface stickiness. Peeled wheat has a pleasing texture when chewed. Because only 15% of the bran remains there is no sensation of toughness.

Table 1 compares characteristics of WURLD wheat and peeled wheat at 14% moisture. The whitest peeled grains come from white common or club wheats. Because of its abundance, however, hard red winter wheat has been emphasized. When peeled, red wheat appears only slightly colored in comparison with peeled white common or club wheats.

Table 1.--Product characteristics

Property	Original wheat	Peeled wheat	WURLD wheat
Color	Brown	White	Yellow-white
Colored bran content	9%	1%	0%
Cooking time	40 min.	25 min.	15 min.
Yield	100%	91%	89%
Density	64 lb/bushel	61 lb/bushel	40 lb/bushel
Protein[a]	12%	11%	11%
Fat[a]	1.4%	1.3%	1.0%
Thiamine[a]	0.39 mg/100 g	0.23 mg/100 g	0.12 mg/100 g
Riboflavin[a]	0.15 mg/100 g	0.09 mg/100 g	0.10 mg/100 g
Germ	Present	Variable	Absent

[a] Analyses made by N. J. Tennis of this laboratory.

Other cereals. Other grains which have been successfully peeled are barley, rye, rice, and oats. None of these, however, provides quite as white a product as does wheat. Oats and barley yield a very bulky fibrous bran in

addition to the peeled cereal. Both oats and barley, when peeled, can be milled to flour, especially for breakfast cereals.

The process. Earlier attempts have been made to peel wheat. The dry or mechanical methods have been judged hopeless for various reasons, particularly because of losses of endosperm (Grosh, 1960). The authors of this report took part with T. Wasserman in tests with an Engleberg mill on wheat at various moistures, with and without abrasives. Not only is endosperm lost in this kind of dry peeling, but the kernel becomes nearly round. Pomeranz (1961) reviewed wet peeling methods, using water and steam. Most of these methods were proposed as preliminaries to milling the wheat into flour. Their objective was to increase flour yields and to improve retention of nutrients located near the outside of the endosperm. Millers have rejected them for various reasons.

Peeling wheat by chemicals has been proposed. Gums, surface-active agents, fat solvents, sulfate ion, and strong acid are among the chemicals mentioned. SubbaRao et al. (1953) proposed 3N hydrochloric acid for peeling

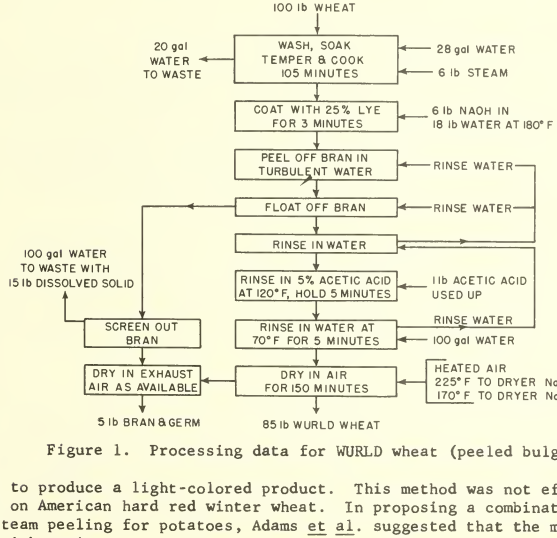

Figure 1. Processing data for WURLD wheat (peeled bulgur).

wheat to produce a light-colored product. This method was not effective, at least on American hard red winter wheat. In proposing a combination of lye and steam peeling for potatoes, Adams et al. suggested that the method would work with grain.

Pretreatments. Some water-soluble nutrients (thiamine, nicotinic acid, pyridoxin) lie in or near the aleurone layer in wheat. Rohrlich et al. (1961) recommended that, before milling, wheat be soaked in water several hours at

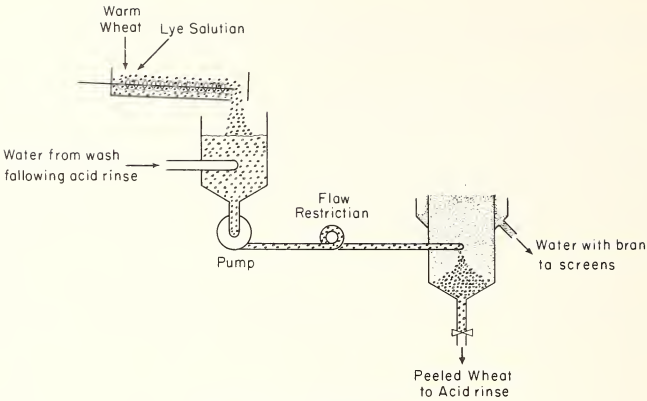

Figure 2. Flow diagram.

140°F. to allow these nutrients to diffuse farther into the kernel. Soaking is even more appropriate as pretreatment for wheat peeling, since the wheat is to be wetted anyway. Such soaking, however, does not contribute to the peeling process itself. It does seem to reduce loss of germ during peeling. For WURLD wheat the wheat should be soaked in water one hour at temperatures rising from 135° to 180°F., held 30 minutes at 189°F., and then steamed at 212°F. for 15 minutes (Smith et al., 1964). The hot wet bulgur is then peeled.

Heating. Peeling can be accomplished without parboiling but some heating is necessary. The grain must be at 180°F. or warmer to react with the lye. Since only a small amount of lye is used, the grain should be warm as well as the lye. One simple heating method is to pass steam through a layer of grain for several minutes. Grain temperature above 180°F. does not interfere with the peeling process. The heating has the additional advantages of inactivating enzymes and killing microorganisms.

Lye coating. Treatment with 25% sodium hydroxide at 180°F. for 3 minutes loosens the pericarp from the seed. The lye reacts with components of the bran, making the used lye dark and viscous. It is therefore economical to wet the grain with just enough lye for the purpose rather than to submerge the grain in excess lye. To do this, we put the warm grain and 20% of its weight of hot 25% solids lye solution (5N-NaOH) into a ribbon mixer. The mixer must wet each kernel quickly and uniformly with lye and keep it that way for 3 minutes. Mixer design should insure positive control of treatment time by moving the grain uniformly through the mixer.

Peeling. The grain drops into room-temperature water after lye coating. The bath removes excess lye and limits lye penetration. This water is that used to wash off the excess acid in a later step. The slight acidity of this

water helps to neutralize the lye and to reduce water consumption. The slurry of water and grain should then be pumped through a turbulent restriction to peel off the loose bran. This restriction can be a loop of tubing which augments the turbulence produced by the pump or a section of tubing containing a rotating mixer.

Flotation. The turbulent stream of water and wheat enters a larger vessel where the peeled grain sinks and the bran floats up with the overflowing water. For easier disposal, the bran can be screened out of the water stream. Separation of bran from grain is complete for wheat and barley. However, much bran sinks with oats and must be removed after drying.

Acid rinse. At this stage, the peeled grain is often discolored by the action of the lye on the aleurone layer. Rinsing the grain 5 minutes in 5% acetic acid solution at 120°F. removes the color. The acid solution does not become foul or dirty. The same acid is used continuously, therefore, by adding about 1 lb. of acid per 100 lbs. of grain treated to make up for the acid neutralized by alkali in the grain. Rough handling of the grain is likely to rub off the germ at this stage. A screw trough conveyor transports it gently. If the germ is to be removed to increase storage stability, more violent mixing may be used here and most of the germ can be removed and recovered. Sulfurous acid will whiten grain more than acetic. The SO_2 will destroy the thiamine completely, however, and there may be some difficulty in eliminating the SO_2 taste from the peeled grain.

Final rinse. The grain is lifted out of the acid rinse and washed with room-temperature water. This may be done countercurrently in another trough with a continuous screw, or on a mesh belt under a water spray. The use of acetic acid does not demand a thorough final rinse because remaining traces of the acid can be evaporated during drying.

Drying. When the grain is separated from the final rinse water, the kernels contain 35% to 45% moisture. At this point, it may be desirable to spray on any solution of nutrients with which it is desired to enrich the product. To eliminate spoilage, drying back to 10-12% moisture should begin immediately. Warm air flowing through a mildly mixing bed of grain is an effective method. Many types of grain dryers are satisfactory. The bran collected at the flotation step can also be dried in air exhausting from the grain dryer.

Costs. Lye and acetic acid are among the cheapest chemicals. Water, power, steam, and waste disposal requirements are modest, and depend on the equipment chosen. Equipment needed is simple and conventional, being confined to pumps, tanks, troughs, and dryers. Our estimates, in advance of continuous pilot plant construction, indicate a cost of about one cent per pound of wheat peeled.

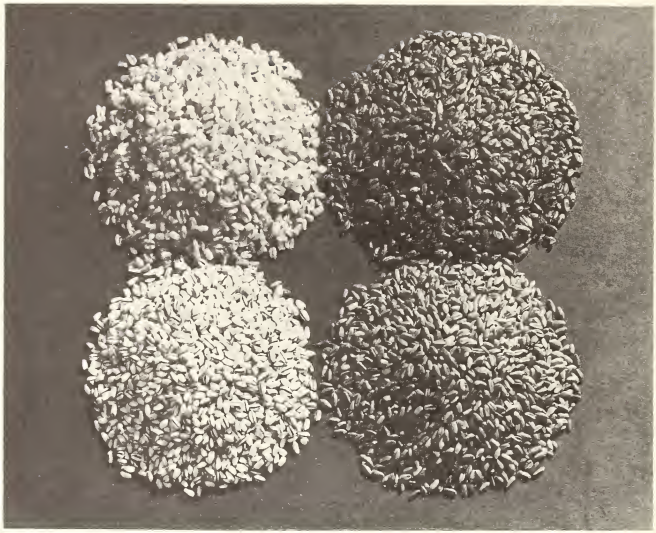

Figure 3. WURLD wheat (peeled bulgur) above at left and peeled wheat (not parboiled) below. Samples of each original wheat are shown at right.

Literature Cited

Adams, Hickey, and Willard. 1960. Food Technol. 14, 1.

Grosh, Shellenberger, and Farrell. 1960. Cereal Chem. 37, 593.

Pomeranz. 1961. Cereal Sci. Today 6, 76.

Rohrlich and Hopp. 1961. Z. für Lebens. Unters u. Forsch. 114 (4), 269.

Smith, Barta, and Lazar. 1964. Food Technol. 18, 89.

SubbaRao, Bains, Bhatia, and Subrahmanyan. 1953. Trans. Am. Assoc. Cereal Chem. 11 (2), 167.

QUALITY CONSIDERATIONS FOR NEW WHEAT PRODUCTS FOR ORIENTAL MARKETS

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In the development of new food products certain factors must be considered that can be grouped under the general term of quality. They include appearance, palatability, storage stability, nutritive value, and others. Dr. Morgan has just explained that WURLD wheat has decided advantages over regular red-wheat bulgur with respect to color, palatability, and very probably acceptability. I will pay special attention therefore to stability and nutritive composition.

In the production of WURLD wheat, cooked wheat is subjected to a brief treatment with a hot lye solution. Immediate concern arises as to what may happen to the stability of constituents in the product. Of these, the fats are probable sources of rancid odors and flavors, which would lower the acceptability of the product after a time. The lye treatment might either diminish or aggravate any problems with fat stability. The small amount of natural wheat fat present in regular bulgur, for example, can be a source of troublesome rancidity, unless the product is stored in a container that permits free access to air.

When properly processed, regular bulgur retains 75 to 98% of its original B-vitamin and mineral contents. Its protein is almost completely retained, as is the nutritional quality of its protein. Because of the longer processing time, exposure to hot lye, and extensive washing, we would not expect WURLD wheat to retain quite so much of the nutritional value of its starting wheat. Careful measurements of retention of nutrient factors are therefore important.

There is no better way to study storage stability than to store the material and examine it carefully at intervals. Acceleration can be obtained up to a point by use of higher than normal temperatures. In the present study three samples of WURLD wheat were stored at three temperatures: room temperature, 90°, and 100°F. Control samples were kept at 0°F. The three WURLD wheats were made from a hard red winter, a hard red spring, and a white club wheat. For some of the samples regular bulgurs made from the same wheats were also stored for comparison.

The samples were stored in cloth bags for two reasons. One is that experience with regular bulgur has shown that it keeps best in containers which allow free access of air and provide for escape of volatile products, such as those of rancidification. A second reason is that cloth bags will most likely be used in the shipment and handling of WURLD wheat.

In our storage tests, samples were presented to taste panels at intervals. The panel members were asked to rank the samples for four attributes: odor of dry product and odor, flavor, and texture of cooked product. Each set of samples for comparison contained a labeled and a hidden control, plus the three higher-temperature samples. Although the tests are still in progress, results after seven months are available for WURLD wheat made from the hard red winter

wheat. Results after six months are available from club wheat, and results after four months for hard red spring.

As expected, samples begin to show detectable changes after several months, particularly at higher temperatures. First to be noticed is a change in odor of dry sample. Later, a change is perceptible in odor of the cooked samples, and finally the change breaks through into flavor of cooked samples. So far no change has been detected in texture of cooked samples, and none is expected on the basis of experience with regular bulgur.

The character of the changes noted is difficult to describe. Rancidity is fairly easy to pin down, but other changes must be lumped into a category one might call staleness. Degree of change is also difficult to evaluate. When the majority of a panel can reliably detect a change between a high-temperature sample and the control, there can be little question that a change has taken place. However, opinion on how much the change has affected acceptability invariably is conflicting. Subjective judgment enters the picture increasingly.

At this point, the value of including the sample of regular bulgur in the comparisons becomes evident. By using a product with which many people have had experience, we can relate the findings on the new product to those obtained with the old. On this basis, then, we can say confidently that WURLD wheat has a storage stability similar to and at least as good as that of bulgur. The type of odor and flavor change noted to date is not yet that of clearly identifiable rancidity. Rather the off-odor or flavors must be characterized as "stale" or simply "off." Detection of the changes would be difficult were not unchanged samples available for comparison. This indicates that the degree of change is yet small.

Now I should like to talk about changes in nutritional factors that occur during processing of WURLD wheat. We have developed information on four samples which include hard yellow winter, hard red winter, and dark hard red winter wheats. The samples ranged from about 10 to 12% in protein content, on a 14% moisture basis. From these samples we prepared bulgur and WURLD wheat. Analyses and animal feeding tests were performed on the starting wheat, the regular bulgur, and the lye-peeled bulgur or WURLD wheat from each sample.

Table 1.--Proximate analyses (average of four samples)

	Wheat	Bulgur	WURLD wheat
	----------percent----------		
Nitrogen	2.2	2.3	2.3
Fat	2.1	2.0	1.6
Fiber	2.7	1.7	0.6
Ash	2.1	1.8	1.7

Table 1 shows the proximate analyses for averages of the four samples. Incidentally, all results are expressed on a moisture-free basis. The individual nitrogen contents varied from 2.0 to 2.4%. This corresponds to a range of protein content of 9.8 to 11.8% at 14% moisture. In each case there was little change in protein content from wheat to bulgur or to WURLD wheat.

This is important because it bears on the interpretation of the protein efficiency ratios which I shall discuss later.

You will note that the fat content of WURLD wheat is lower than that of the wheat from which it is produced or the corresponding bulgur. This no doubt results from greater removal of bran; in addition some of the germ is lost.

The fiber content of WURLD wheat is much lower than that of regular bulgur, because of complete removal of the bran layers down to the aleurone. Bulgur of course is partially debranned mechanically to arrive at the 1.7% figure. Three of the wheat samples were similarly debranned before analysis, as they are for feeding experiments. Therefore the fiber value shown here for wheat is from a single sample.

The ash content shows that some diminution occurs upon lye peeling. This probably comes about through bran removal and leaching during processing.

Table 2.--Analyses for minerals (averages of four samples)

	Wheat	Bulgur	WURLD wheat
Phosphorus, %	0.44	0.43	0.40
Calcium, ppm.	670	790	420
Iron, ppm.	28	29	39
Copper, ppm.	6	6	6

Table 2 shows analyses for some nutritionally important minerals. You will note that the phosphorus and copper contents do not change materially in the production of WURLD wheat. The calcium and iron analyses show some changes. However from more extensive analyses of bulgurs produced in different plants throughout the country, these values were found to vary considerably and apparently were influenced by the water supply and the equipment used in processing rather than by the process itself.

Table 3.--Analyses for vitamins (averages of four samples)

	Wheat	Bulgur	WURLD wheat
	---------mg/100 grams----------		
Thiamine	0.38	0.34	0.22
Riboflavin	0.099	0.085	0.055
Niacin	6.5	6.4	5.7
Choline	230	240	220
B-6	0.37	0.30	0.21
Folic acid	0.065	0.059	0.048
Pantothenic acid	1.00	0.75	0.68

Table 3 shows the average of four analytical values for six of the water-soluble vitamins and choline. Several factors are operating simultaneously during processing to bring about the observed changes in levels of these vitamins. Choline, on the fourth line, is the only material which shows substantially no change. The change in niacin, however, is not very large. I have prepared Table 4 which shows approximate percentage changes in these

analyses for the two processes, wheat to bulgur and wheat to WURLD wheat. This will permit us to compare the various changes more easily.

Table 4.--Processing losses

	Wheat to bulgur	Wheat to WURLD wheat
	percent	
Thiamine	10	40
Riboflavin	15	45
Niacin	<5	10
Choline	0	5
B-6	20	45
Folic acid	10	25
Pantothenic acid	25	30

Table 4 shows more clearly what has happened to the vitamin content during processing. There are several factors. First, bran and some germ are removed in processing and these tissues, in general, have higher levels of the vitamins than the remainder of the kernel, the endosperm. However, this is further complicated by possible movement of vitamins from the bran and germ into the endosperm during processing, for example as happens during the parboiling of rice. Of course heat is involved and the vitamins show differing stabilities toward heat. And last, in the case of WURLD wheat a strong alkali is used, which again influences stability. Thus, these figures represent the net changes that occurred as a result of several factors.

There were some losses in the bulgur process. These agree well with what has been found previously for similar samples except that the average loss of thiamine is lower than is often found.

The thiamine, riboflavin, B-6, and folic acid contents of WURLD wheat are substantially less than those of bulgur. Losses in five of these factors from wheat to WURLD wheat range between 25 and 45%. Nevertheless, WURLD wheat retains significant quantities of these nutritionally important vitamins.

Table 5.--Comparison with flour

	WURLD wheat	Patent flour
Phosphorus, %	0.40	0.10
Calcium, ppm.	420	180
Iron, ppm.	39	9
Copper, ppm.	6	--
Thiamine, mg/100 g.	0.22	0.07
Riboflavin, "	0.06	0.06
Niacin, "	5.7	1.0
Choline, "	220	190
B-6, "	0.21	--
Folic acid, "	0.048	.013
Pantothenic acid, mg/100 g.	0.68	0.56

In Table 5 WURLD wheat is compared with patent flour, a common food eaten in large quantities around the world. The data for flour were obtained

from Composition of Food, Agriculture Handbook No. 8, U. S. Department of Agriculture, for the first seven items, down through niacin, and the remaining data were taken from Calhoun et al., Cereal Chemistry 37: 755 (1960).

WURLD wheat is equal to or superior to flour in all the mineral and vitamin components listed. With the exceptions of riboflavin, choline, and pantothenic acid, WURLD wheat has concentrations of the components which are two to five times greater. Of course, flour is commonly enriched with thiamine, riboflavin, niacin, and iron and perhaps enrichment should be considered for WURLD wheat also. However, WURLD wheat is so much superior in content of several of the vitamins that for many purposes it could suffice without enrichment. If it were to be enriched, the quantity required would be less for certain vitamins, notably niacin and thiamine. Also, an enriched product would have higher levels of B-6, folic acid and pantothenic acid, which are not commonly included in enrichment mixtures used with flour or rice.

There is one more important bit of information I should like to present. Table 6 shows the protein efficiency ratios for the four samples of wheat,

Table 6.--Protein efficiency ratios (average four samples)

Wheat	1.18 (1.32 - 1.08)
Bulgur	1.15 (1.28 - 1.02)
WURLD wheat	1.02 (1.07 - 0.94)

bulgur, and lye-peeled bulgur. Again, average values are shown. Figures within parentheses show the range of values found for the individual observations. Protein efficiency ratio or PER is a measure of protein quality which reflects the balance in a product of the amino acids that are essential in human nutrition. Values for animal proteins are higher than for vegetable proteins. In fact, an animal protein, casein, is used as a reference material in the experimental determination of PER. It is assigned a value of 2.5, and other values are corrected to this base.

The values shown here for wheat and bulgur are very nearly equal and are quite typical of values we have obtained in the past. In each of the four, the PER for WURLD wheat was always a little lower. Table 1 shows that the protein content changed very little during the lye peeling to produce WURLD wheat. If there had been a decrease in protein we might have suspected a loss of soluble protein by leaching or with the removal of bran, which might have had a PER different from that of endosperm protein. Soluble wheat protein has a higher potential biological value than the gluten protein of the endosperm. But, since the protein content is little changed, it must mean that there has been no obvious disproportionate loss of soluble protein and probably some alteration has occurred in the protein to reduce the PER. Also, it is logical to expect that there has been some destruction of the limiting amino acid, lysine. In any event, the PER of about 1 is still superior to that for patent flour of 0.8 reported by Hove (Cereal Chem. 22: 289-95, 1945).

In summary, based on our research to date, we can say: (1) The storage stability of WURLD wheat appears to be at least the equal of that of regular bulgur. (2) WURLD wheat retains the level of minerals and some of the B-complex vitamins nearly as well as does bulgur. Thiamine, riboflavin, B-6, and folic acid are less well retained. (3) WURLD wheat contains higher levels of the major B-vitamins than wheat flour. (4) The PER of WURLD wheat is reduced only slightly from that of the whole wheat from which it is made.

On all of the foregoing counts, WURLD wheat is a good food product, well suited for use in countries where food supplies are short and nutritional imbalances common. The quality factors herein considered support the belief that the product can have a bright future in Oriental food markets.

THE GATT NEGOTIATIONS - WHAT IS IN THEM FOR WHEAT?

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It is a privilege to speak on the problems of wheat as they relate to current trade negotiations under the auspices of the General Agreement on Tariffs and Trade (GATT) in Geneva. I am sure that you are aware that much of what happens in the "Kennedy Round" of GATT negotiations with respect to wheat and other grains, and for that matter agricultural trade as a whole, will be influenced largely by the policies and the negotiating proposals of the European Common Market (EEC). Therefore before speaking directly on the GATT negotiations, it would be well to briefly review and make some observations on grain policy in the Common Market.

On August 1, 1962, the EEC put into force a common system of variable levies against imported grains, including all types of wheat, from the USA and other non-member exporting nations. This system applies a levy, calculated each day, as the difference between the lowest world priced wheat, delivered at Common Market ports, and the internal member country target price which represents the market price which internal support measures set as a goal for Common Market farmers.

During the past two years of experience with this new grain levy system, we have found that: (1) It has already resulted in increased prices to Common Market wheat farmers, particularly in Holland, Belgium, and France. (2) It threatens to result in even higher prices in the future, particularly in France. (3) The levy system always protects, to some degree, the internal market for local domestic producers from equal competition from outside sources and threatens to increase this level of absolute protection. (4) It threatens to extend to France an inordinate amount of price preference to insure complete market dominance of French grain supplies, particularly wheat, in Germany, Netherlands, and Belgium before imports are made. (5) The higher prices and protective measures are resulting in uneconomic increases in wheat and other grain production at the expense of expanding world grain trade.

There are three Common Market decisions yet to be made with respect to grain within this variable-levy system. The first is the general level of grain prices that will be finally settled upon in harmonizing the different price-support levels now in effect in the Common Market countries. The EEC has not yet been able to agree on what the common internal wheat price level is to be, with levels continuing to range from $2.35 a bushel in France to over $3.00 a bushel in Germany. The lowest possible price-support levels in the Common Market will mean a lower levy against imported wheat. Also, the lowest possible support-price level will have some influence on the amount of wheat and other grains produced in the Common Market, and thereby will influence the level of domestically produced supplies and future net imports.

The second decision to be made is the relationship of wheat prices to other grain prices in the final policy. Most of the wheat produced in Western Europe is soft, with low protein content and low baking strength. We firmly believe that EEC price policy should set support prices for wheat and feed grains at substitution levels, so that Common Market produced wheat can freely flow into feed compounding uses and also to the extent that Common Market farmers will find it as attractive to produce feed grains as they have found it to produce soft wheat. We base this observation on the fact that if Common Market wheat prices are supported artificially above feed grain prices, much of future increases in grain production will come in wheat, and that shifts may also take place from feed grains to wheat. This could mean that the EEC would become a large surplus producer of soft wheat, and would precipitate two further actions: (1) EEC policy would further discriminate against imported wheats and force Common Market mills to use more soft wheat in place of imported hard wheats; and (2) increased denaturization and export subsidies would become necessary to further dispose of surplus soft wheat supplies in other world markets. At any rate, we do not believe that the Common Market would long continue this greatly differentiated price policy because of consumer pressure against lower-quality flour and bread, particularly in Germany, Holland, and Belgium; and also because of the additional burdensome treasury costs of denaturization and export subsidies. Therefore in the end they would virtually be forced to adopt substitute price levels between wheat and feed grains anyway, and would only have distorted the total grain market by not doing so initially.

The third decision is the amount of price preference that will be extended to French produced wheat and other grains to move into Germany, Belgium and Holland, and perhaps more importantly the present and future associated countries of Greece, Turkey, Ireland, Spain, Austria and the former British and French African colonies. Our government foreign agricultural experts appear to have been much too optimistic about the necessity of the Common Market to import hard wheats to maintain or improve the quality of their bread flours. It has been demonstrated that with enough price preference for French wheat inside the EEC, over any imported wheat, the European milling industry could rapidly move into those techniques which enable them to make high-quality flours out of low-protein soft wheats. This will be particularly true if the price preference for the byproducts is also substantial compared to the price of imported mixed-feed components.

These three EEC grain policy decisions involve a considerable amount of detail in the structure, operation, and administration of the variable-levy

system. These details involve marketing margins, withholding taxes, transportation backoff rates, feed substitution values, price equivalents relative to intrinsic milling and compounding values, and selection of basing points for minimum prices in deficit supply areas at which imported wheats are brought in relative to the guaranteed prices to producers in surplus areas of the community.

The USA is participating in the "Kennedy Round" of the GATT negotiations and has proposed that a "commodity agreement" covering all grains be negotiated guaranteeing access to the Common Market by outside grain exporting countries. These guarantees are to be made in spite of the production and marketing effects of the variable-levy system, the levels of internal grain support prices, and possible increased preference for internally produced grain arising out of policy decisions yet to be made, just previously mentioned. This proposed "commodity agreement" is to include guarateed minimum Common Market import quotas for wheat and feed grains on a global basis, with step increases in these quotas to reflect future increases in demand and utilization. This means that USA has proposed that the Common Market agree to buy a minimum percentage of their needs of wheat and feed grains, regardless of how much they produce themselves or what their year-to-year domestic supply situation is. French spokesmen have stated that guaranteed import quotas of grains from outside the EEC are unacceptable as a guarantee of access to the Common Market for USA and other exporting countries.

Previous to this French statement, the Common Market Executive Commission in Brussels stated that it was impossible for them to negotiate anything with respect to trade in grains until the Common Market itself has decided upon its internal harmonized grain prices and marketing policies. This is about where the GATT negotiations with respect to cereals (wheat and feed grains) are today. The US proposal for guaranteed access through minimum import quotas is unacceptable to the French, and the Common Market has not yet decided on its internal policies to the extent that it can direct its Executive Commission to negotiate on some other basis.

There is the possibility that the French, as the major producer of grains in the Common Market, will make or has already secretively made an alternative proposal to extend some measure of import assurances by the EEC for quality wheat and feed grains from exporting countries, such as USA, Canada and Argentina, in exchange for market guarantees for French grain, mostly soft wheat, into emerging market in the Near East, Africa and Asia, along with a program to help dispose of further French soft wheat surpluses under a world food program similar to PL 480 in the remaining underdeveloped countries. Such a proposal would mean that in exchange for a declining share of the EEC grain market, we would share other foreign markets with the French and also contribute to financing of further surplus disposal of French grains.

We would be remiss if we do not recognize right now that any agreement which includes international market-sharing devices denies us the benefits of most efficient least-cost production and trade. In this connection, Professor Lawrence Witt, of Michigan State University, has said in his National Planning Association paper, "Toward Transatlantic Agricultural Policy Bargaining," that "market sharing and use of commodity agreements would impose a straight jacket upon international trade. Government action would be required before pricing

demand would become meaningful to exporters; uncertainties and internal political pressures would force most nations into nationalistic plans and programs." Professor Witt further points to US sugar policy, where every major and minor political crisis has resulted in increases in importing-country production and decreases in proportion of international sugar trade.

It is difficult to visualize how an agreement establishing guaranteed access and market-sharing arrangements can long survive when price levels and internal trade-bloc preferences are allowed to take their own course. It is not logical to expect importing countries to continue present levels of imports when protective prices and effective internal market preferences result in increased domestic production to the extent that the need for imports are drastically reduced. Because of secretive handling of both GATT and bilateral negotiations by the US and the EEC on the problem of grains, and judging from conflicting reports that have been appearing in the press in the last 30 days, the situation on grains in the "Kennedy Round" is to date most unclear and uneasy.

Six questions need to be fully explored and explicitly answered before a clear understanding of the negotiating problems, and the US negotiating position, can be gained by those of us who are affected economically, and before confidence in negotiations relating to both agricultural and industrial tariffs can be assured:

1. Cannot negotiations be brought about to lower Common Market support prices and protective variable measures as an approach to more freely competitive access to the Common Market for wheat and other grains from the US and other exporting countries?

2. What assurances could be made that even if guaranteed market access arrangements were agreed to by the EEC, high Common Market support prices and production policies would result in greatly increased grain production which would have to be disposed of in other world markets at the expense of USA exports elsewhere?

3. Might not the establishment of EEC grain import guarantees mean only short-run market access, and that in the long run dislocated world trade in grains would be further aggravated by continuing to ignore the actual trade barriers of support prices, variable levies, and other trade-prohibitive tariff measures?

4. What are US alternatives in GATT grain negotiations if all present proposals should fail to be accepted?

5. Can, and if so how will, the US withhold GATT industrial tariff reductions if agricultural trade with the EEC is not accommodated?

6. How widely will decision-making be shared in determining what will be acceptable as a satisfactory deal for agriculture, including grains, and particularly wheat, in the GATT negotiations?

There should be little doubt in our minds that we are fast approaching the precipice of an international agricultural crisis. Recent information from government agencies concerning the GATT negotiations pointed up the fact that our negotiators are struggling to reach some kind of compromise to take care of agriculture, including grains and importantly wheat, to enable general negotiations covering the wide range of industrial items to proceed on schedule after the first of the year. We must keep in mind that any such compromise

agreement must specifically center around the question of feed grains and wheat. It also must be realized that details of a compromise may be kept secret at the insistence of US negotiators as well as officials of the EEC and other GATT participants, because of possible concessions on international trade in grains therein contained.

Two possibilities have now more predominately arisen with respect to agriculture in the GATT negotiations: (1) a compromise agreement to bring heretofore incompatible positions into line among participants may be hastily framed to meet the prescribed schedule for industrial negotiations, and in this haste something less may result for agriculture in sacrifice for successful industrial trade relations, or (2) a compromise may be in the making which will result in industrial negotiations proceeding on schedule and rapidly outdistancing any real progress in agricultural negotiations, bringing about a long-feared possibility that, with industrial negotiations accomplished, it will be impossible to withhold industrial tariff agreements until agriculture is brought up from its position of no progress.

Under these clouded and unstable negotiating conditions for agriculture, it seems logical that a complete review of our agricultural negotiations is called for, with substantial consultation with producer and trade groups, both to bring about a clear understanding of the present status of negotiating problems, the prospects for success under present positions, an analysis of alternatives, and to aid in the development of new proposals that appear to be called for. My subject is "The GATT Negotiations - What Is In Them For Wheat?" A definitive answer is not available, but judging from the present status, it could well be trouble for efficient producing and exporting countries like ours.

NEW WHEAT GRADES AND THEIR EFFECTS

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It has long been my firm conviction that through cooperative efforts of all sectors of our industry we will find solutions to the complex problems facing agriculture. Each segment has played a major role in our remarkable progress to date--and let us remember that we have, indeed, achieved much.

Consider our abilities pertaining to one product--wheat. Presently we produce, store, market, and transport--every year--a sufficient quantity to feed twice the population of our nation. None would disagree that we have the capability to exceed our present volume. Few would disagree that it is imperative that we do so. Certainly each segment of this industry must play a far greater role if we are to meet the awesome challenge of the future. Cargill is eager to shoulder its responsibilities and we welcome opportunities for growth and progress which conferences such as this provide.

Just as I believe in industrial cooperation, so, too, am I an advocate of a direct and candid approach. Someone has said that there is a lazy human preference for fighting yesterday's ideas instead of tomorrow's problems. My

sole objective is to discuss my subject as it pertains to tomorrow's problems and not to rekindle the ashes of past disagreement.

On the first of June this year new grade standards for wheat became effective. The primary changes from the old standards are: (1) There is a new grade of "heavy" in winter wheat. (2) The allowable limits of "wheats of other classes" have been changed and a new subclassification, with very narrow limits, called "wheats of contrasting classes" has been added. "Contrasting classes" for each class have been designated. In hard red spring and hard red winter, durum and white wheat are considered contrasting classes. In durum, any class other than durum is considered contrasting. In soft red winter, durum is a contrasting class. And finally, in white wheat, durum and hard red winter are contrasting. (3) Dockage is not a grading factor per se; however, it is of course most important in determining the net quantity of wheat delivered on a contract. Under the revised standards, dockage is expressed in the nearest half percent, whereas it formerly was expressed in increments of full percents. (4) A new grading factor, called Total Defects, has been added. This is the total of the factors of damage, foreign material, and shrunken and broken. The limits for each grade are: No. 1, 3%; No. 2, 5%; No. 3, 8%; No. 4, 12%; No. 5, 20%.

When these revised standards were first proposed, strong arguments--both for and against--were voiced. The proponents contended that they were necessary to enhance the position of US wheat in world markets and that the revised standards would create wider acceptance of American wheat by foreign buyers. The advocates declared that the proposals would adjust the standards to improvements that have been made in cultural and handling practices in the growing of wheat and the better-quality farm crop that has resulted. They contended that the new standards considered the improvements that have been made in methods of drying, cleaning, and handling grain, as well as methods of measuring quality. Considerable data were published to show the desirable effect the proposed changes would have, in the opinion of the proponents.

Objections to the new standards were primarily limited to the proposals for stating dockage in the nearest half percent, to the low limits proposed for the new factor of total defects, and to certain of the limits of other classes. In the case of dockage, the opponents presented economic studies to document that the new proposal would probably result in the shipment of a higher percentage of dockage--in the case of spring wheat--than was the case under the old standards, and that dockage on winter wheat shipments would be no less than was formerly the case. These studies showed that cleaning costs would be prohibitive, hence necessitating the continued shipment of the same quantity of dockage or more. Those opposed to the proposals pointed out that the data published by the Department of Agriculture documented the fact that the dockage of wheat exported was well below the dockage content of wheat receipts at markets throughout the channels of commerce. Therefore statistics published by the proposal's proponents effectively refuted any statements or implications falsely accusing exporters of shipping dockage--dirty wheat.

As I mentioned before, the new factor, total defects, is the total of damage, foreign material, and shrunken and broken. The limits of damage and foreign material continue as before. The limits for shrunken and broken

kernels have been reduced. The new factor tends to make the other three meaningless. First, it is the same as that factor of shrunken and broken alone but includes the other factors. Second, it amounts to the total of 1/2 each of the other factors. The data published by the Department of Agriculture showed that the average exports of grade No. 1, under the old standards, contained 3.7% total defects, whereas a total of 7.5% would have been permissible. Again, the proponents' own facts refuted the allegations by some that exporters were needlessly shipping an inferior product.

Opponents to the revision thoroughly analyzed the practical effects of the new proposal. Since damage cannot be controlled--in other words, the damage content of grain cannot be removed by cleaning--these studies were narrowed to the cost of cleaning in order to reduce the content of foreign material and shrunken and broken. The conlusions were that the actual losses in cleaning--in order to gain a grade--would range from 2 to 10 cents per bushel. The opponents, therefore contended that very little if any at all of grade No. 1 could be exported and that it was entirely conceivable that the supply of grade No. 2 could be decreased--especially if a particular year's crop was characterized by relatively high damage content.

Objections to the proposals regarding the narrow limit of contrasting classes were raised where, in some geographic areas, several of the contrasting classes are produced in the same localities. This is true of the Pacific Northwest where hard red winter and white wheat are produced and in the North Plains where hard red spring and durum are raised. In addition to arguments pertaining to dockage, contrasting classes, and total defects, opponents emphasized the practical problems involved in handling wheat under the new standards, which would also add to the cost factor. Even though the objections were strong, the new standards were implemented. Since the revisions were designed to improve our nation's position in international wheat markets, we must focus our attention on exports to determine the effect these changes have had.

In discussing wheat exports, we must remember that there are two types of foreign buyers. First there are commercial buyers, who purchase on a "cash on the barrel-head" basis. All of the West European nations, Japan and the Philippines in the Far East, and certain nations in Central and South America and Africa are in this category. Last year we could also include the Soviet Union. Second there are concessional buyers. They are able to purchase grain as a result of assistance of our government under the Food for Peace program. India, Pakistan, and Brazil are prime examples of buyers included in this category.

Since the mid-1950's the great bulk of our wheat exports have been under the concessional sales programs. There has been an increasing awareness of the importance of capturing a larger share of the commercial world markets--of exporting more wheat to those cash buyers who can freely select from products offered by every wheat-exporting nation in the world. There is no doubt that the new wheat standards were designed primarily to enhance our position with these commercial buyers.

Let us now examine what has happened since we began working under the new standards. During the first quarter of this marketing year--July through

September--commercial exports of wheat and the wheat equivalent of flour totaled 35 million bushels. This was only 18% of our total wheat and flour exports. Last year, during the same period, commercial exports of wheat and wheat equivalent of flour totaled 58 million bushels--and these shipments reflected 33% of total exports. Therefore, with the new standards, we have shipped 23 million bushels less this year than we did for the same period under the old standards a year ago. Our percentage of commercial exports to total exports under the new standards is only a little over half the percentage we maintained last year under the old standards.

Canada is our principal competitor in commercial world markets. Canada's commercial exports for the first quarter this year are running nearly twice as large as they were for the same period last year. Good wheat crops in Europe and Japan have adversely affected our commercial exports so far this year. Also, it should be noted that during July, Canada was still shipping wheat to the Soviet Union, whereas most of our shipments to that destination were completed prior to this marketing year. Nevertheless it is still obvious that our commercial shipments have declined while Canada's have increased. It is apparent that the new grade standards, per se, have not enhanced the position of US wheat in world markets.

And what of the quality of wheat we have exported? To the best of my knowledge there has not been any appreciable change in the physical characteristics of wheat shipments between this year and last year--between the new standards and the old standards. As was expected, the actual content of dockage on shipments has been no lower than last year. However, since the method of stating dockage has been revised, an added cost is incurred on exports.

So far this year the content of those factors which make up total defects is about the same as last year. Since the allowable limits have been considerably narrowed, however, grade No. 1 in the hard wheat classes is no longer available for export from this country. Buyers who formerly desired this grade are now making do with grade No. 2. As anticipated, the costs of cleaning to up-grade wheat have proved excessive. There are added risks in that even following the expensive cleaning operation, the wheat still might not grade No. 1. Exporters are unable to offer this high grade unless they can at least recover the known costs which they would incur. Foreign buyers, on the other hand, have shown no propensity to pay any more than a minimal premium for a grade No. 1 over No. 2. Since they prefer the lower grade--unless the difference in price would be far less than the cost of manufacturing the higher grade--we have, for all practical purposes, seen the deletion of US grade No. 1 in international wheat trade.

What do commercial buyers think of our new standards? It would be incorrect not to acknowledge that they prefer them to the old standards. The revisions--by limiting the permissible content of various undesirable factors in each specific grade--have at least created the impression in the minds of the buyers that the quality of US wheat shipments has improved, or will improve. Even though, as we have seen, this is not necessarily true, the better image for US wheat certainly does not hurt our position.

Even if we accept the premise that the new standards have some public relations value, we have seen that this has not, so far, increased our wheat exports. The statistics indicate the contrary. There is a simple explanation. My subject today solely covers grade standards; however, I would like to stray from it for just a moment to mention the reason, as I see it, for this apparent contradiction. Most of us in the grain trade have consistently believed that price is the single most important factor in determining the salability of US wheat for export. Practice has in our opinion proved this to be correct.

Commercial foreign buyers determine the origin of wheat they purchase by selecting that product which is most favorably priced relative to competing products of a generally similar quality. (The word relative is most important.) In other words, buyers predetermine the relative value of competing products. They buy that which is relatively the most reasonably priced. By their actions so far this year we can conclude that American wheat has not been competitively priced--in the opinion of foreign buyers--relative to wheats of competing nations. Also, I have heard little to indicate that foreign buyers have materially changed their ideas of the value of US wheat compared with Canadian, for example, since the new standards became operative.

There is another possible effect of the new grade standards which we cannot yet measure at this time. In my opinion, this is probably the most important consideration and pertains to concessional exports, which are the great bulk of our wheat exports. For the first quarter of this year over 80% of our exports were in this category and nearly 70% of our total wheat exports have been under Title I of PL480. This program provides the mechanism whereby dollar-poor or soft-currency countries pay with their own currencies at prescribed rates of exchange. Most of these funds are held on deposit in the buying country for the account of the US government and are earmarked for eventual spending within that country.

Our Department of Agriculture prohibits the export of wheat which grades less than No. 2 on this type of business. What does this mean? First, if India, for example, is allocated 100 million dollars for the purchase of wheat, she must buy grade No. 2 regardless of whether No. 3 or No. 4 is available at appreciably lower prices, and regardless of whether the lower grades would fill the buyer's requirements equally as well. Buyers are prohibited from spending their aid dollars for the maximum quantity of any given product which could be made available to them. They are not permitted to decide for themselves the question of the relative importance of quality vs. quantity. Second, there is an increasing concern about our ability to continue supplying a product to concessional buyers that will grade No. 2. The problem of contrasting classes in the Pacific Northwest has proved to be a real headache for export elevators. Should this problem become more severe, the supply of grade No. 2 could be considerably decreased. In the Southwest there is concern over possible increase in damage and/or shrunken and broken content. Any material increase in either of these factors, or a combination of them could result in decreased supplies of hard red winter which would grade No. 2.

Any limitations on the availability of wheat grading No. 2 would not adversely affect commercial buyers. They are free to purchase any grade of US wheat they desire. In addition, their economic independence permits them

to purchase from other nations as well. But what of the concessional buyers? They must look to the US for their supplies. It would be a sad commentary if they were limited in securing adequate food supplies simply because sufficient stocks of wheat of a certain numerical grade may not be available.

Our wheat producers also have an interest in such a problem. Certainly they need an outlet for their wheat--be it grade No. 1, 2, 3, or 4. When grade restrictions are placed on foreign consumers of our product, an immediate marketing restriction is automatically placed on American wheat growers. Economists and humanitarians alike have long wrestled with the problem of transferring food from areas of surplus to areas of deficit--from areas of plenty to areas of poverty. It would seem to me that this arbitrary determination of grade "suitability" merely compounds an already complex dilemma. Certainly this is a predicament where we already have too many questions and too few answers--too many problems and too few solutions. I submit that some of the solutions and some of the answers are to increase, not decrease, the quantities of food this nation can supply to the underdeveloped areas of the world.

It is clear that the new grade standards have not accomplished that for which they were designed and have even created some new, potentially dangerous problems. Does that mean that I suggest we simply rescind the changes, return to the status quo, and continue operating as we did in the past? Not at all!! David Sarnoff once said that the great menace to the life of an industry is industrial self-complacency. Certainly agriculture cannot afford to drift into this sort of mire. My recommendations fall into two categories.

First, we need a reappraisal of grading factors and a new determination of those which are truly meaningful in designating wheat quality. We must strive for more adequate description of the quality of our products to foreign buyers. General comments from foreign buyers have been primary reasons for revisions in the grading standards. However, in my opinion, these comments have often been incorrectly translated. The net effect is that we have increased the cost of handling grain in this country and have done little to serve better the needs of buyers abroad. The US has more complex and more highly technical procedures for determining grain grades, or quality, than exist anywhere else in the world. Most Europeans rely solely on empirical methods. They have no knowledge of the type of sieve we use for measuring shrunken and broken kernels, for example. They do not know what we mean by the term "foreign material." On our recent durum mission to Europe we learned that, in France, the major problem was not the content of shrunken and broken kernels in our shipments. Rather, it was the amount of small, undersized kernels. These are not separated in our grading process, but they are discarded by French Semolina mills. This is one instance where the new grade standards did nothing to satisfy French desires. They were then--and are now--concerned with a problem of a different nature.

Second, after determining those factors which are universally important, we must find the way to measure these factors. Time and excess expense are not luxuries we can afford throughout all the channels of grain commerce. Therefore we must have methods of quality determination that are accurate, quick, and

inexpensive. We have some specific recommendations we feel would be desirable. I submit them for your study and comments.

(1) We need a mechanical measure of kernel hardness. Presently this is done visually, which is far from satisfactory. We separate hardness into the categories of soft, mixed, yellow hard, hard, and dark hard. Would it not be more desirable to classify wheat as soft, semi-hard, and hard? Some have suggested use of the barley pearler to determine hardness. This requires further study. In any case, if we can accurately, quickly, and cheaply measure the hardness of wheat--if we can, for example, differentiate between the hard winter produced in the Western Plains from that of the central states--then we will have made real progress.

(2) We need something better than test weight to indicate probable flour yield. A kernel count is probably a more accurate measure but inexpensive equipment for this determination must be designed.

(3) We need more realistic measurement of kernel damage. The present methods of visual determination are inaccurate, time-consuming, and arbitrary. They measure the "appearance" of damage, not actual damage to quality and, hence, provide no measurement of probable safe storage life.

(4) Above all we need to adopt tests that: (a) measure an important characteristic, (b) can be made by the unskilled, (c) can be made quickly, and (d) can be made with inexpensive equipment.

We are an industry with a twofold international objective. First, we must continually strive for a larger share of commercial world markets. We dare not be satisfied until we have assumed a position of dominance in this field. Second, we have an obligation to the underdeveloped, hungry nations. Hopefully, they will some day enter the ranks of the commercial buyers. Now they need the benefit of our abundance. Our methods of determining grain grade and quality must make it possible to serve the needs of both objectives. In addition, we must provide the mechanism whereby our growers can easily market all that they are able to produce, for, in the long run, our problem will not be surpluses but our ability to produce enough for the world's needs.

UTILIZATION RESEARCH TO IMPROVE UNITED STATES COMPETITIVE POSITION IN WORLD DOLLAR WHEAT MARKETS

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Those who attended or have read the report of the First National Wheat Utilization Research Conference in Lincoln, Nebraska, two years ago will recognize, as my talk develops, a good many points in common with talks given at that time by Ed Seeborg and Wayne Bitting. They dealt with the quality problems faced in the marketing of our wheats abroad. I will deal today with changes in our research program and with new work undertaken to help solve just those problems.

Table 1 shows a breakdown of our wheat exports to major world importing areas for the fiscal year 1961. This particular year was selected for a couple of reasons. First the anticipated export total for the current year is <u>about</u> what we exported in 1961. Figures I have seen for the intervening years have

Table 1.--Estimated wheat exports, F.Y. 1961

	Dollar sales	Government programs	Total
North and Central America	19.5	3.0	22.5
South America	14.1	52.8	66.9
Europe (West)	106.8	41.0	147.8
Europe (East)	0.8	55.4	56.2
Africa	9.2	62.5	71.7
Asia	54.7	252.3	307.0
Total Exports	205.1	467.0	672.1
			...millions of bushels

not been broken down in quite this way, and the past couple of years, especially last year, have been somewhat unusual. The features I want to emphasize are clear enough and represent our current situation in aspects to which I wish to call your attention.

First, please note in the first column that Western Europe and Asia are our biggest cash customers. In Asia, the bulk of dollar sales was to Japan and the bulk of nondollar sales to India and Pakistan. The dollar sales to Central and South America are quite significant, but the quality problems involved in those regions that might be amenable to a utilization research attack are fairly well covered by the approaches being made to the European problems and to the somewhat less distinctive Japanese problems.

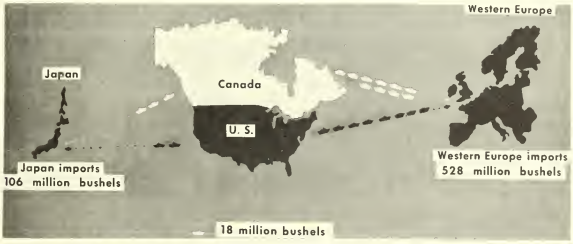

Figure 1. Wheat exports to major dollar markets. Each symbol represents 18 million bushels.

Figure 1 directs attention to the Western European and to the Japanese markets. Also it illustrates that in these markets we compete directly with Canadian wheats. Again the figures were made up from an earlier year but will probably not be too far away from what is expected this year. The main point is that Canada is outselling us in these dollar markets. Why is this so?

First, let us recognize that these markets are not only cash markets, but large markets. We face the stiffest competition, either for price or for quality, that our several exporting competitors can muster. Secondly, both markets are so-called quality wheat markets, for the most part. By quality wheats I mean strong wheats--wheats with high levels of protein and high

baking strength. This is particularly important in the European market because of the necessity for blending strong imported wheats with the weak wheats grown in Western Europe in order to obtain flours strong enough for bread products.

The preferred and standard imported wheat in Western Europe for many years has been Canadian Hard Red Spring. There are several reasons, but an important one is that the Manitoba wheat is dependably high in quality. Another important one is that in most European countries the chemical treatments used in the United States, Canada, and Britain to obtain maximum baking performance simply are not allowed. This is important because spring wheat flours as a general rule do not require such maturing treatments to perform well. On the other hand, flours from hard red winter wheats are much more dependent upon this induced maturing to perform at their best.

I want to caution you that this situation is not quite so simple as you may infer from what I have just said. Spring wheat flours generally do respond to maturing, and some winter wheats do about as well without as with maturing; but by and large when maturing is prohibited, winter wheats are penalized more than spring. I should also add that it is no solution to say that we could avoid this entire problem by shipping our own spring wheats to Europe to compete directly with Canadian spring wheats. This would be simple, except that we normally don't have enough high-quality spring wheats beyond our own needs to supply all export needs. Spokesmen of the milling and baking industries assure us that there seldom is a surplus of strong, high-quality wheats that could go into export in any substantial volume. With the recent emphasis on growing stronger varieties, however, this situation is getting better. This year, I understand, we have an exportable surplus of high-quality wheats. Nevertheless, if we could develop new and effective methods to improve baking performance under the restrictions imposed in Europe, our chances of capturing a larger share of the quality market would be improved.

I have spoken of the maturing of wheat flour but have not explained it. When wheat is milled, the flour does not perform at its best right away. Without any treatment at time of milling, the flour will gradually improve in baking performance over weeks or months, until an optimum is reached. To allow flour to attain this state by natural means has long been prohibitively expensive for the milling industry. For many years now, treatments with various oxidizing agents during milling have been used to speed up this process. The treatments have been most effective and are widely regarded as sound and safe. Even so, the governments of all continental European countries prohibit on a general basis the treatment of food materials with chemical agents, with very few exceptions, and flour maturing agents are not among them. Some of you are thinking that this is not true in the Netherlands. As I understand it, the Netherlands does not allow flour bleaching or maturing treatments, but the regulations on the books simply are not enforced.

Figure 2 shows just how important the maturing effect can be. The first four loaves are from the same winter wheat flour. Starting at the left we have the pup loaf produced with no added oxidizing agent--in this case, no potassium bromate. The second, third, and fourth loaves have increasing amounts of the agent up to a total of 6 mg. of bromate per 100 grams of flour. The response is dramatic and, I must grant, a little more so than usual. The final loaf is

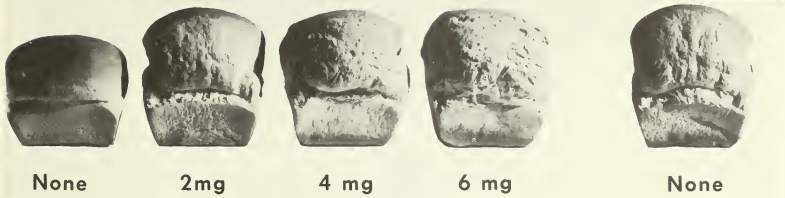

Figure 2. The importance of maturation in flour.

from untreated spring wheat flour. Its performance is good without treatment and its response to treatment, while measurable, is not large. Moreover, the requirement for optimal performance is less for the spring wheat flour. Admittedly, somewhat extreme examples were selected to illustrate the point.

The point I have been leading up to is that, under suitable circumstances, hard red winter wheat flours can compete effectively with hard red spring. This fact is confirmed by the large segments of the milling and bread baking industries in this country who operate satisfactorily without any spring wheat flour at all. Likewise, other companies get along very well without winter wheat. The problem is to enable European millers and bread bakers to do as well. The solution we are striving for is to learn how to mature flours artificially and quickly without using the agents not permitted in Europe on an unproved health hazard basis.

Another aspect of this spring-versus-winter wheat question has to do with the blending properties of the two types of wheat when mixed with the very soft wheats grown in western Europe. In Belgium, for example, government regulations have required that domestic and imported wheats must be blended before milling. This causes unnecessary problems because the miller must cope with a mixture of very soft, easily reducible wheat kernels and, if high-protein imported spring wheats are used, of hard, vitreous, difficult-to-grind kernels. Logic as well as experience tells us that a mellower hard wheat would result in easier milling and very likely better end products. Again, as a general rule, hard red winter wheats are significantly softer and mellower than spring wheats.

On the other hand, millers in Germany are permitted to blend flours from soft local wheats and imported quality wheats after milling. This is a somewhat better situation but still not the best, because flours from flinty vitreous hard wheats are quite granular and sharp compared to flours from soft wheats. No matter how carefully blended, there is always the chance for

inadvertent classification during handling, as well as differences in rate of water uptake during mixing development and in tolerance to mixing and fermentation. Mellower wheats and flours again would be easier to handle in efforts to make uniform products. With traditional baking procedures and equipment in much of Europe, these factors have not been as important as they are becoming with the modernization beginning to take place. Softer and whiter breads are taking over a larger share of the market each year, and more and more mechanization in baking is being resorted to in meeting rising labor costs, labor shortages, and the like. I don't mean to say that baking in these countries is on the verge of becoming like ours, but trends are well along.

With regard to this blending aspect, there is still another factor of importance. European millers use as much of their local wheats and as little of the expensive imported quality wheats as they can, for obvious reasons. The long-standing rule of thumb has been that the stronger the imported wheat, the larger the quantity of the soft domestic wheats it would carry. This is not always true, according to some spokesmen of the trades over there, but there is little available information to document this belief. Furthermore, relative carrying capacity seems not to have been a factor considered in selecting either our spring or winter wheats for export to this discriminating market. Our current research takes cognizance of this gap in information.

One final word, before I get into specifics of projects, has to do with the fact that all along the line, we as yet have too little of the right kind of basic information about wheat composition to answer the vexing problems of quality and quality differences in any of the many use situations where wheat is converted to baked products. A large part of our research program at the Western Laboratory and elsewhere is devoted to finding out the details of composition of the lipids, proteins, and carbohydrates of wheat. Further, we are studying the ways that these individual components act with one another in doughs, batters, and simple solutions to bring about the effects that are so important in wheat processing. Information of this kind is essential for progress in any and all of the specific problems to which I have already referred. With this introduction, I would now like to take up some details about our program to aid in the marketing of our wheats abroad.

<u>Basic Research to Achieve Objectives</u>

Isolation and characterization of flour constituents . . . .
- Proteins
  - Lipids
    - Enzymes . . . . and

Relation of each to . . . .
- Flour maturing mechanisms
  - Blending value with weak flours
    - Mixing and baking qualities

The outline above is a summation of the areas I have discussed: first, the generally applicable basic research on proteins, lipids, and enzymes, and then the pointed attention to the areas relating to specific problems concerned with flour maturing, with blending values, and with the broadly important mixing and baking properties of flour.

Within the Western Laboratory we have several projects concerned with isolation and characterization of proteins, lipids, carbohydrates, and some enzymes. This program includes lipoproteins that are present in flour naturally and may be formed during mixing and baking. In addition, we have recently placed a research grant with Professor Mark Stahman at the University of Wisconsin for a comprehensive study of the oxidizing and reducing enzymes in wheat flours. In this way we are making use of experts on this type of enzymes to supplement and complement the work in progress in our own laboratory. As information is developed under the grant, it will be funneled into the studies underway in Albany on the mechanisms involved in flour maturing. We will be particularly interested in the findings regarding the oxidizing enzymes, because there is evidence that they are implicated in mechanisms of maturing of flour.

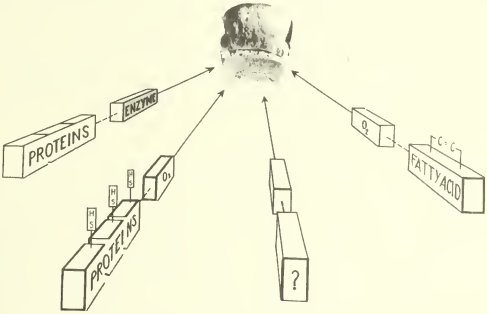

Figure 3. What is the mechanism of maturation of flour?

Figure 3 illustrates the approaches that must be made to this type of problem. On the left the boxes indicate that direct enzyme action on proteins may be involved in flour maturation. This may be speculative because enzymes usually are not very effective at moisture levels in flour. There is evidence to the contrary, however, and more is being currently obtained under a PL480 grant we sponsor at the National Institute of Agronomic Research in Paris. Mr. Olson will refer to this work on Saturday. He will also mention other projects which are evolving new basic information about flour constituents that we and others can use in working out answers to practical problems.

The second row of boxes illustrates the attention being received by the sulfhydryl groups on flour proteins as they may be oxidized by any one or all of several possible agents to bring about the characteristic improving effects in baking values of flours. Atmospheric oxygen almost surely plays an important role. The oxidative effects of such flour treating agents as chlorine dioxide, potassium bromate, and potassium iodate are likewise strongly implicated in oxidation of sulfhydryl groups. We do not yet understand as well as we need to just how oxidation of sulfhydryl groups brings about the increases in flour strength, but several promising lines of research are being pursued in our laboratory and elsewhere.

On the extreme right the boxes indicate the implication of oxidative enzymes in flour maturing. The unsaturated fatty acid in flour can become oxidized with or without the assistance of oxidative enzymes. The fatty acid hydroperoxides thus formed can in turn contribute to the oxidation of sulfhydryl groups, for example, on flour proteins. Similarly, the free radicals formed during the oxidative breakdown of flour fats can possibly participate in maturing effects. These effects, again, can be enzyme mediated. There is precedent information in various biochemical systems. This area is extremely complex, but again workers in several cereal laboratories around the world are busy on this angle, as are we.

The blank boxes at the right center indicate that there may be other factors or other possible mechanisms that we don't know about. This is possible, although it seems likely that the two lines of work involving oxidation of sulfhydryl and enzymatic effects will be the most productive. The enzymatic aspects provide an opportunity to bring about proper maturing of hard winter wheat flours, as well as spring wheat flours, by so-called natural means, not involving chemical treatments. This would be a big accomplishment but not the limit of usefulness of information coming out of this work. Fundamental information will be helpful in many ways in our own industries.

I want to turn to two contracts we have arranged with people here at Kansas State which were designed to provide information on this problem of making wheats more attractive in European markets. The first has been in effect for a little over a year and has to do with a comprehensive examination of compositional differences between hard red spring and hard red winter wheats. The investigations will be looking for leads that help to explain the distinctive differences in behavior that characterize these important classes of our nation's wheats. Studies of this kind have been conducted on several occasions in the past, but as each new generation of methods and tools come along, the chances for a successful study are greatly increased. With the rapid advances in our knowledge of wheat constituents in the past 3 or 4 years, as a result of powerful new research tools, we are quite optimistic about this project.

On Saturday morning, Dr. Pomeranz will describe some of the advances made in relating composition of hard wheats to baking value. I might point out that, while the final objective of this contract and some of our other work is improvement in marketability of hard winter wheats, the work under the contract project here will be equally useful for winter and spring wheats. Both are examined and studied in equal detail.

The other contract here at Kansas State, activated this past summer, has to do with blending and carrying capacities of our dominant hard red winter wheats, as well as representatives of our hard red spring wheats. The specific objective is to determine baking procedures and conditions permissible in European practice that will elicit maximum carrying capacity of HRW flours in blends with either weak European flours or of weak flour plus strong HRS wheat flours. Further, it is the objective to establish characteristics of HRW flours which will reflect accurately their potential carrying capacity under European baking conditions and permit selection of US wheats best suited for European markets.

The emphasis here is on European practice. Rather than relying on baking and milling procedures used in this country, resort will be made to procedures used in Europe. These differ from ours markedly in some instances. They may have little value for our own ways of using flours, but they tell the critical story about use of flour in markets we wish to reach. The project will certainly provide information about how best to use and how best to select wheats that will go into the baking industries in Western Europe. The information will guide us in convincing European wheat users of the specific merits of our wheats. It seems appropriate that these two projects are located here in the heart of our winter wheat region.

Thus far I have dealt mostly with the European market, mostly because of the particular and somewhat peculiar problems faced there. The Japanese market is different. Their traditional use of wheat in products such as noodles has posed no problem in meeting their requirements with our western soft white wheats. The same has been true for the soft wheats going into their growing cake and pastry markets. In the past year or two, however, changes in the variety picture in the Pacific Northwest have caused some disturbances.

We understand that flours from Gaines wheat tend to have higher viscosities than are desired for certain bakery products. Such a characteristic is undoubtedly inherent in the variety, but to my knowledge no one has yet demonstrated what specific constituents determine the viscosity of a flour suspension under conditions used for the test. Undoubtedly, the proteins contribute importantly to viscosity as measured, but which proteins? Total quantity of protein is only very loosely correlated, so we must look at variations in quantity of individual components as soon as we are able to. Recent research progress to be discussed by Dr. Lawrence and by Dr. Dimler is bringing this capability closer and closer. The manpower needed to get at some of these problems sooner is becoming an important handicap.

In the bread wheat side of the Japanese import picture, the milling and baking industries in Japan pose pretty much the same problems as are met in our own country. Because bread consumption in Japan has evolved mostly since the war, the milling and baking industries are modern and similar to ours, Ed Seeborg emphasized in Lincoln two years ago. Our principal problem in Japan is head-on competition with Canadian spring wheats--not for blending with weak local wheats as in Europe, but for producing directly good, high-quality bread flours. Good success has been achieved in the past couple of years by grower organizations and FAS in demonstrating to the Japanese the advantages of high-quality winter wheats with their mellower flour characteristics.

The problems in Japan can be grouped pretty much with those we have within the United States. On this basis, our current research program, especially in the fundamental areas, is as much oriented towards Japan as it is to our own industries, and what will benefit one will likewise benefit the other. Even some of the work pointed at European problems will be helpful.

As you well realize, we have other dollar markets that are important in the aggregate, but few pose problems other than those covered already by the problems met in Japan, Europe, or here at home. The Philippines pose one problem a little bit peculiar in that a stronger than normal flour is required

to make their famous "pan de sol" rolls. One reason is the high ambient temperatures under which they are made. This has seemed not to have been too serious to our exporters, however, and as we gain more experience with flour behavior under the higher than normal temperatures in the continuous-mix type of bread production, it can be translated to the "pan de sol" situation.

In laying out our program, I have refrained from going into very much technical detail. In future meetings there will be opportunity to review in more depth some of the experimental work and findings. You will have noted that all the work has not begun at the same time. We have had to expand our program to take in these new areas as we could. A phase or two remain to be activated, but most of the work aimed at European problems is underway. I would like to express our appreciation for the sustained and active support we have received from the growers' organizations and others in getting our program more closely geared to current needs. Support and assistance have taken many forms and we will continue to welcome and seek the assistance, counsel, and support of all segments of the wheat industries to keep our program as responsive as possible to their needs.

EXPANDING FOREIGN MARKETS FOR DURUM AND DURUM PRODUCTS

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North Dakota State University, Fargo

There was a time, as recent as 1961 or 1962, when a discussion of the expansion of foreign markets for durum wheat would have been highly academic. A series of production problems had created a shortage at a time when the world, and particularly the United States, was faced with a surplus in bread-type wheats. However, durum, which accounts for approximately 4% of the world trade in wheat, occupies a special position in the world wheat economy. Because of its desirability as a raw material for the milled product called semolina, this type of wheat has been independent, to a certain extent, of the marketing problems that have affected other types.

Durum differs botanically from the common bread wheats. Wheat belongs to the genus *Triticum*; the two major species of this genus which are grown commercially for food are *Triticum durum* and *Triticum vulgare*. The many varieties of *T. vulgare* grown throughout the world largely for bread-type products have 42 chromosomes, whereas the varieties of *T. durum* have only 28. In addition to these differences, *T. durum* usually is more tolerant to arid growing conditions and produces a large, very flinty kernel which contains more pigments than its plant cousin.

Data pertaining to the production, trade, prices, and consumption of durum wheat are not readily available. In fact, the foreword to the report on durum wheat, prepared by Hulugalle and Hiscocks (1), indicates that world data on this subject are not well documented. Consequently, this report attempts to summarize the potential use of durum wheat and durum products from the standpoint of the United States wheat industry. Background was obtained by personal experience in the United States, a visit to Western Europe in conjunction with a durum wheat trade team sponsored by Great Plains Wheat and

Foreign Agricultural Service of the USDA, supplemented by public and private reports (2,3,4).

Although there has been a steady expansion of demand for durum wheat, there has been considerable fluctuation in supplies. Consequently, in international and domestic markets, prices have tended to fluctuate dramatically. Since World War II, durum has generally commanded a premium over high-grade hard wheats in international markets. However, when price becomes excessive, substitution occurs. Because the major part of the durum crop produced in Italy, Russia, and United States is consumed in their respective domestic markets, Canada and Argentina are considered the primary exporting nations, where production normally exceeds domestic utilization. Approximately 45% of the world exports arise from Canada. Consequently, the production and reserve supplies available in Canada usually establish the price trend in world exports.

Because statistics on utilization of durum are not available readily, this review presents a summary of utilization of durum for pasta products. However, it is understood that significant quantities of durum are consumed for cous-cous in North Africa, bread in Italy and the Mediterranian area, "pancake" bread and porridge-like foods in the Near East, chapatties in India and Pakistan, and various forms of wet or dried noodles in Southeast Asia, China, and Japan.

Durum supplies in North America. On July 1, 1964, stocks of durum wheat were reported at 40.3 million bushels in all storage positions, 12% less than the 46.0 million on hand a year earlier and considerably more than the 5.1 million on hand on July 1, 1962 (5). Production for the 1964 crop is estimated to be approximately 61 million bushels. The October 1964 supply is now estimated at 101 million bushels, the largest on record (6).

The relatively favorable growing conditions and the release of new rust-resistant varieties with greater production capacity than hard red spring wheats have created the bountiful supply. For the state of North Dakota, which produces about four-fifths of the US durum, the 1964 crop was the fifth largest in 46 years of record. On July 1, 1964, the Canadians had about 40.3 million bushels, nearly double the 23.3 million available on July 1, 1963. Their 1964 crop is expected to be about 34 million. Needless to say, the Canadian durum supply likewise reflects abundance.

Production of pasta products. The quality of durum wheat for semolina milling is primarily associated with its ability to produce a high yield of semolina, free of visible specks, and macaroni of the desired brilliant yellow color (2). In normal years, little attention need be paid to protein content in the selection of durum wheat for milling purposes; however, in the manufacture of "long goods" it is necessary to maintain protein above a more or less ill-defined minimum, ca. 11%, to avoid undue stretching during drying.

Pasta products consist of dough made from semolina, flour, or farina by the addition of about 25% water; the dough is mixed and formed under pressure into various tubes, rods, sizes and shapes. These products are usually dried under controlled humidity for one to three days, to produce a low moisture

product of excellent keeping quality. In certain areas, the products may be utilized immediately after forming and without drying.

Utilization of pasta products. In Western Europe and North America, as personal incomes increase, per capita consumption of wheat tends to decrease. Under these circumstances, however, there is a tendency for consumption of pasta products to increase. This preference for pasta has increased the demand for durum. Economic factors influence the proportion of durum included in finished products. In certain countries, such as France and Germany, pasta products are made entirely from durum. In Italy, about 50% durum is used. As living standards increase, the proportion of durum utilized probably tends to increase.

Regional utilization. Most of the durum produced in the United States is used domestically for pasta products. Owing to the distinct amber color, high gluten content, low moisture, and nut-like flavor, about 28 million bushels are in demand annually for such products as macaroni, spaghetti, vermicelli, noodles, and various short goods. A relatively small portion of durum products is diluted with farina to produce a blend. In general, about 90% of the pasta products produced in the United States are thought to be produced entirely from durum.

Currently, the "average" American family consumes macaroni products once a week. If we could merely increase this use to twice a week, the American consumption would increase to approximately 50 million bushels per year. Moreover, this increase would probably not displace other wheat products in the American diet. Usually hard rolls, Vienna bread, and other specially baked goods form an intregal part of a dinner which features pasta products.

Doubtless one of the largest opportunities for expanding US consumption of durum products lies in the restaurant and institutional food business. The tendency for more families to eat out more frequently appears to afford an opportunity to increase the broad spectrum of macaroni dishes offered for consumption. However, effort must be expended in training chefs and cooks to prepare these food products. A delicious dish of spaghetti can be cooked and served in about 15 minutes. Too many chefs however tend to hold spaghetti on steam tables or in refrigerators and to pour hot sauce over the precooked pasta products. The result is a most invariably slimy, sticky mass which is unappetizing and a discouraging sight to the consumer. Education needs to be expanded to improve the quality of main as well as side dishes based upon macaroni products.

The expanding number of convenience foods offered in supermarkets and grocery stores also offer an opportunity for expansion of pasta products. The food industry is rapidly increasing pasta products and sauces in the convenience food lines, and it can be anticipated that the housewife will find that it is less time-consuming to prepare macaroni dishes than to prepare the more time-consuming other foods.

Statistics from the National Association of Macaroni Manufacturers indicate that during periods of stress, when durum was not readily available and blends of durum were used more extensively, sales of macaroni products

declined. Currently, the American people consume about 8 pounds per capita annually of macaroni products. This represents a 40% increase in the last 16 years. As a consequence, the tonnage of durum products consumed in the USA has doubled in this past decade and a half.

Western European potential. During March in 1964, a commercial grain man, two North Dakota grain producers and a University professor toured five European countries to assess the current and potential market for US durum. This trip was sponsored by the Foreign Agriculture Service of the U. S. Department of Agriculture in cooperation with Great Plains Wheat, Inc. The team toured Italy, France, Switzerland, West Germany, and the Netherlands. We visited representatives of about 80% of the total durum milling capacity of these countries. Our contacts with Europeans and US agricultural attaches led us to believe that a realistic, short-term export goal of 12 million bushels of durum could be possible. This would be about a 2.5-fold increase of current exports. In recent years, we have been exporting about 5 million bushels per year. Moreover, this potential could be doubled in the long term if better marketing practices and durum varieties having more acceptable characteristics could be presented to the European buyers.

Problems in exporting US durum. What are some of the difficulties one is faced with in attempting to expand foreign markets for durum products? The United States is a unique nation; we produce wheat primarily for a large domestic processing industry and, only until recently, we have not had abundant supplies available for export. Consequently European customers, who are most interested in reliable sources of a known quality in sufficient volume for requirements, are not familiar with our product. One reason is that no single organization in the United States is exclusively marketing durum. If one were in Europe and desired to purchase durum, one would turn to a grain importer who could supply wheat grown in many countries and offer many qualities and many prices. The decision to buy a single lot would be dictated frequently by political and economic expediency and the usual pressure of availability at an attractive price.

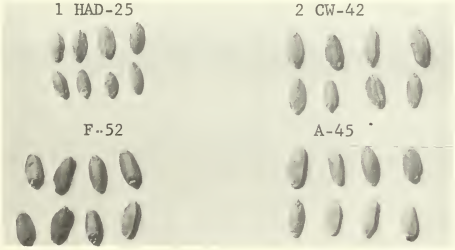

Figure 1. Kernels of durum wheat obtained from a flour mill in Marseilles, France. The samples are: Upper left = No. 1 Hard Amber Durum - 1000 kernels weighed 25 grams. Upper right = No. 2 Canadian Western Amber Durum - 1000 kernels weighed 42 grams. Lower left = French durum - 1000 kernels weighed 52 grams. Lower right = Argentinian durum - 1000 kernels weighed 45 grams.

Is our durum the type Europeans want? The two major varieties, Wells and Lakota, which represent most of our acreage, have been bred for rust resistance and a short strong straw. They yield well; they have good quality. From the technologists' standpoint, they possess relatively small kernels which place our durum at a distinct disadvantage. Canada and Argentina, for example, produce durums which weigh about 45 grams per thousand kernels, compared with about 25-35 grams for our product. To Europeans, the small kernel simply means that they can get fewer pounds of semolina per pound of wheat. Consequently, our durum must be sold at a discount (approximately 10%) to be attractive to the European miller. If Canadian or Argentinian durum with larger kernels is available at reasonable price, it will be purchased in preference.

Advantages. Does American durum have some advantages? Indeed, we were informed on several occasions that color, lack of contamination with insects, and relatively low moisture content are factors which are decidedly in our favor. If we capitalize on these attributes and improve kernel size, it would seem realistic that we could improve our position in the export market. Fortunately, two varieties in the development stage appear to have reasonably acceptable processing quality and good kernel size. We trust that through further research these problems may be alleviated. Let us consider the situations in several of the countries that the team visited. Table 1 presents a summary of the potential.

Table 1.--Durum wheat summary of imports and potential

	Italy	France	Swiss	Germany
Needs (x 1000 tons)	500	500	90	350
Imports (x 1000 tons)	200	450	90	350
U.S. share				
Now, % mkt.	--	18	10	6.5
Future, % mkt.	Nil	35	30	22.5
Future (tons x 1000)	--	177.5	27	80
Current		81	9	23
Increase		96	18	57
Future (10^6 bu.)		6-7	1-1/2	3-4

Switzerland. Switzerland produces no durum but the Swiss use 100% durum in the pasta industry. They need the high-quality product because they blend with lower-grade semolina, imported from Italy. Because of the influx of Italian labor, current import requirements are about 4.5 million bushels. As the Swiss appear to be creatures of habit, they have become satisfied with the Canadian product and are reluctant to change. Their concept of value suggests that US Hard Amber durum should be sold $6 to $10 per metric ton below the comparable price of No. 2 Canadian durum.

The impression of the team was that consumption of durum products will continue to increase in Switzerland because of imported Italian labor. With reasonable education, promotion and an aggressive marketing, we feel that we could enjoy about 30% of this market and possibly export about one million tons to Switzerland.

France. France is a wheat-exporting nation but not a major producer of durum. The French consume about 20 million bushels of durum a year and produce

about 2 million. By law, 100% durum semolina must be used for pasta products. Before recent political changes, France obtained much of her durum from North Africa. Now, new import patterns appear to be emerging.

The color and low moisture content of US durum are considered desirable by the French. The small kernel size is a decided disadvantage. To clean wheat, the French use a sieve with holes that are 30% wider and twice as long as the dockage sieve used in the United States. Consequently they feel that our grain has an excessive cleanout, which they refer to as "non-millable material." Since they import grain on a weight quota basis, the weight of "unmillable faction" makes the extraction of semolina from US durum appear low. The French are considering new supply sources and may be receptive to increased usage of American durum. Provided we can furnish a reasonable quality, we should be able to market 6 to 7 million bushels annually to France.

West Germany. West Germany produces no durum and imports about 12 to 14 million bushels. Currently, only 5 to 10% of these imports are purchased from the United States. Seventy to 80% are purchased from Canada. The Germans prefer the large kernel and high specific weight typical of the Canadian durums. The outlook for increased export to West Germany would be similar to that of other nations. If we can present a reasonable product, it may be possible to secure some 20% of their business or approximately 3 or 4 million bushels per annum.

Italy. The prospect of sale to Italy does not appear to be very bright. The Italians produce durum for export in their southern region. Because of economic problems, the heavily populated northern portion consumes pasta products which are made from blends of hard and soft wheat. Consequently, the quality of pasta products varies considerably with geographic location in Italy. It is rather improbable that the United States could hope, in the foreseeable future, to export significant quantities of durum to Italy.

Japan. The consumption of wheat and wheat products in Japan is becoming increasingly important. Currently, about 40% of the wheat is consumed in the form of noodle-type products. The probability of further increases in this hard-currency area is very promising. Recently, Japanese officials have visited the durum and macaroni laboratories at Fargo and subsequently have purchased a substantial quantity of our durum.

England. Like the countries previously described, England has experienced an increase in consumption of pasta products. However, it has consisted largely of an increase in imports of finished goods. Macaroni products rather than durum wheat have accounted in general for the increase. With the relatively low per capita consumption, 0.7 lb., which is about 10% of the US and 1% of the Italian, it would appear that England could become an attractive market for finished goods.

Effect of new grades. Earlier this year, the grain grades were revised with the intent of improving the export potential. Figure 2 shows a comparison of the grades of the 1964 durum crop; the 1957 revised standards are shown on the left and the 1964 revision on the right. It would appear that the 1964 revision has created two new grades, 1 heavy and 2 heavy. Each represent about

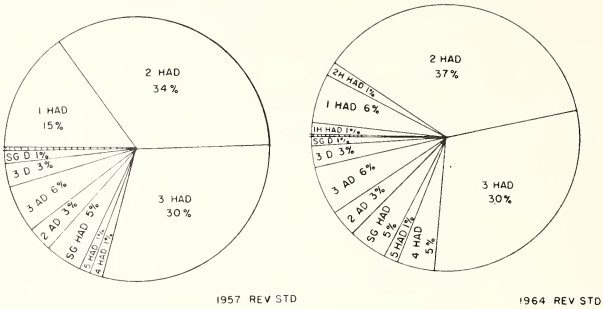

Figure 2. The typical grades of the 1964 durum crop. On the right, the samples were graded according to the 1964 revision of the official grain standards. On the left, the same samples were graded according to the 1957 revision of the official grain standards.

1% of the total crop. The percentage of 1 HAD has diminished and the 2 HAD increased slightly. However, 79% of this year's crop would have graded 3 HAD or better under the 1957 revision; under the 1964 revision, 75% graded 3 HAD or better.

A summary of changes in grades due to the revision of the grain standards is shown in Table 2. Eighty-four percent of the 1964 crop would be graded the same if either the 1957 or 1964 revision were used. Of the 14% that received lower grades due to the new standards, two-thirds was lowered by total defects and one-third by contrasting classes.

Table 2.--Summary of grades due to revision in standards (1964 durum wheat survey)

% of total	Effect, if 1957 rev. std. applied
84	No change in grade
2	Graded lower (heavy)
14	Graded higher
	a. 67% total defects
	b. 33% contrasting classes

In the European Economic Community (EEC), it has been proposed that durum wheat be graded on the basis of three major categories shown in Table 3. When samples of 1 HAD and 3 HAD were graded by a French technologist, it was reported that there appeared to be very little difference in these grades. Both had nonvitreous wheat, broken and shrunken, and thin grains in excess of the desired limits.

Improvements Proposed. How can we improve the position of the United States durum in the world market? The team has given considerable time and

Table 3.--Comparison of commercial U.S. durum wheat samples by French and new U.S. standards

	HAD 1	HAD 3
I. Test weight (78 K/H)	79	78
II. Non conforming elements (24%)		
A. Wheat (20%)		
Non-vitreous (16%)	26.2	25.1
Contrasting classes (4%)	0.42	0.25
B. Grains (3.5%)	(10.34)	(13.63)
Broken	4.22	5.92
Shrunken & thin	4.74	4.92
C. Miscellaneous (0.5%)	(0.29)	(0.28)
Foreign material	0.04	0.08
Foreign seeds	0.25	0.20
III. Vitreous grains (76%)	(75)	(75)

thought to these problems and suggests the following areas for further work. A major area is that of better education and promotion. It would seem highly desirable to prepare and distribute descriptive booklets describing our product, durum, our marketing system, and above all, our grading system. To be effective, this material should be published by the United States government in foreign languages appropriate to the potential durum user.

Personal contact between US representatives and durum users should be maintained. There is no substitute for this method of solving problems, clearing confusion, and facilitating business. The Canadians have used their scientists for European contacts for years with good success.

A uniform trade certificate and a uniform method of certification by inspectors should be adopted. This is necessary to develop more confidence in the minds of the foreign buyers who frequently feel that virtually any person associated with the grain business can issue a certificate. On many of our visits, considerable time was spent in informing the millers about the issuance of grade certificates and the operation of the United States wheat grading system.

Information should be distributed regarding the stocks available for export. It would be highly desirable to have stocks continually maintained in exportable positions so that foreign buyers could know that adequate supplies are available to satisfy their needs time after time.

Aggressive and consistent government pricing and subsidy policies are considered of utmost importance and will have a direct bearing on our international sales potential.

Undoubtedly, the most important area that needs corrective action is the development of new durum varieties with larger and more uniform kernels. At the same time, the desirable quality and color characteristics of existing varieties should be maintained. To implement this concept, the recent agricultural appropriation has provided for increased personnel to work in the agronomic and cereal technology areas so that research work can continue at a faster pace than heretofore was possible.

Literature Cited

1. Hulugalle, M. L., and Hiscocks, M. G. A. A world survey of the production trade, prices and consumption of durum wheat. International Wheat Council, London, SW.
2. Geddes, W. F. In Cereal Grains, The chemistry and technology of food and food products, ed. by M. B. Jacobs, p. 591. Interscience Publishers, New York, N. Y. (1944).
3. Hoskins, C. M., and Hoskins, W. G. In Macaroni Production. The chemistry and technology of cereals as food and feed, ed. by S. A. Matz, p. 274. Avi Pub. Co., Westport, Conn. (1959).
4. Irvine, G. N. In Durum Wheat and Paste Products. Wheat chemistry and technology, ed. by I. Hlynka, p. 529. American Association of Cereal Chemists, St. Paul, Minn. (1964).
5. Anonymous. Semi-annual durum report. Grain Market News, August 1964.
6. Anonymous. Wheat Situation. Economic Research Service, USDA, October 22, 1964.

FEED VALUES OF WHEAT FOR RED MEAT AND POULTRY PRODUCTION

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The fact that wheat of various types and wheat milling by-products can be utilized effectively in feeding farm animals is well established by practical feeding experiences. In spite of rather extensive experimentation, we still do not clearly understand some differences in performance, especially of poultry, when wheat is substituted for corn. Examination of compositions of cereal grains does not provide an insight to the differences. However, differences in composition provide a partial basis for relating values of grains to one another.

Table 1 presents data on protein, fat, fiber, and metabolizable energy contents of corn, types of wheat, and barley. Protein content especially

Table 1.--Composition and metabolizable energy (chicks) of cereal grains (dry basis)

Grain	Protein (%)	Fat (%)	Fiber (%)	M. E. Cal/lb. dry matter
Corn (5 samples)	10.5	4.3	2.4	1830
Wheat, hard red	17.2	2.5	3.2	1610
Wheat, soft red	14.0	2.1	3.0	1650
Wheat, soft white	10.5	2.2	2.5	1710
Average of 5 samples				1660
Barley	7.9--15.7	1.8--2.8	5.2--7.5	1420 (5 samples)

Hill, F. W. et al., Poultry Sci. 39: 573.

varies widely and is influenced by conditions under which wheat is grown, as well as other factors such as fertility of soil and variety. There is rather characteristic difference between the fat contents of corn, wheat and other cereal grains, and more will be said later on as a possible reason for

Table 2.--Amino acid composition of cereal grains on dry matter basis

Amino acid	Corn	Wheat	Milo
	%	%	%
Arginine	0.4	0.8	0.4
Histidine	0.2	0.3	0.3
Isoleucine	0.5	0.6	0.6
Leucine	1.2	1.0	1.6
Lysine	0.3	0.5	0.3
Phenylalanine	0.5	0.7	0.5
Threonine	0.3	0.4	0.3
Tryptophane	0.1	0.2	0.1
Valine	0.5	0.6	0.6
Methionine	0.2	0.2	0.1
Cystine	0.1	0.2	0.2

N.R.C. Publication 585.

Table 3.--Amino acid content and availability in wheat

Amino acid	Content % of N x 6.25	Availability %	Amino acid content of Marquis[1/] % of N x 6.25
Arginine	4.38	96.4	4.5
Histidine	2.51	98.8	1.6
Isoleucine	3.03	95.0	4.5
Leucine	6.82	95.4	6.4
Lysine	2.90	92.8	2.2
Methionine	1.35	94.9	1.2
Phenylalanine	5.15	96.9	5.0
Threonine	2.83	92.2	2.7
Tryptophane	1.35	93.2	--
Valine	4.50	93.2	4.4
		95.0	

1/ From McElroy et al., J. Nutr. 37: 329.
Kurken and Lyman, J. Nutr. 36: 359.

Table 4.--Free-choice consumption of whole grains by turkeys (28 weeks)

Feed or whole grain	Feed consumed			
	Toms		Hens	
	lbs.	%	lbs.	%
Starting mash	8.2	8.1	8.2	12.4
Developing mash concentrate	24.0	23.8	10.1	15.3
Wheat	41.6	41.4	31.9	48.2
Corn	17.9	17.8	12.0	18.1
Oats	8.4	8.3	3.8	5.7
Barley	0.6	0.6	0.2	0.3
	100.7	100.0	66.2	100.0

Robertson and Carver, W.S.U. Bulletin 402.

differences in feeding value. As cereal grains are used in poultry feeding as a source of energy, the metabolizable calories are of tremendous importance. Table 1 shows that wheat of various types is lower in this component than corn.

Table 5.--Influence of protein content of wheat on need for supplementary protein by chicks

Protein content -- % of wheat	Protein content -- % in diet	Av. chick wt. at 4 weeks	Feed/gain
		g.	
11.3	--	224	2.8
13.2	17	215	2.5
16.5	--	109	4.1
11.3	--	236	2.3
13.2	19	220	2.3
16.5	--	189	2.9
11.3	--	252	2.1
13.2	21	250	2.4
16.5	--	229	2.5

March and Biely, J. Nutrition 42: 565.

Table 6.--Effect of cereal grains and fish solubles on chick growth

Grain	No fish solubles		4% fish solubles	
	Av. wt. 4 wks.	Feed/gain	Av. wt. 4 wks.	Feed/gain
	g.		g.	
Corn	371	1.94	376	1.92
3/4 corn, 1/4 wheat	388	1.94	399	1.88
1/2 corn, 1/2 wheat	381	1.86	402	1.87
1/4 corn, 3/4 wheat	392	1.89	404	1.86
Wheat	381	1.88	401	1.85

No. 5 Western Wheat.

Summers, Pepper and Slinger.

Table 7.--Use of corn and wheat as grain in chick diets

Grain	Av. wt. 4 wks.	Feed/gain
	g.	
Corn	444	1.71
Wheat	449	1.72

Summers *et al.*, Poultry Sci. 38: 816.

In many instances the relative values of grains are based simply on metabolizable energy.

Even though the protein of cereal grains is much lower than that of soybean meal, meat scrap, and fish meal, it is highly important in animal production, simply because of the large proportion of grain in most rations. Therefore, amino acids in cereal protein are also important. Examination of data in Table 2 for corn, wheat, and milo does not show any marked variation in the amino acids listed, with the possible exception of arginine. The significance of these small differences in relation to differences in performance of animals fed has not been clearly established. Availability of amino acids, as well as the absolute amount in a feed ingredient, is important. The evidence in Table 3 indicates that most of the essential amino acids are highly

Table 8.--Effect of different cereal grains and combinations on broiler growth and feed efficiency

Cereal grains(s) used	Average weight and feed conversion--4 weeks							
	0*		2.5*		5.0*		7.5*	
	Wt.	FE	Wt.	FE	Wt.	FE	Wt.	FE
	g.		g.		g.		g.	
Corn	604	1.65	622	1.58	637	1.57	638	1.52
Wheat (Gaines)	574	1.68	584	1.66	599	1.64	590	1.62
Milo	590	1.72	573	1.68	591	1.64	604	1.61
3/4 corn, 1/4 wheat	576	1.64	615	1.60	633	1.54	619	1.55
1/2 corn, 1/2 wheat	596	1.66	607	1.61	618	1.61	621	1.57
1/4 corn, 3/4 wheat	592	1.68	605	1.62	591	1.62	601	1.59
1/3 corn, wheat, milo	597	1.68	606	1.60	604	1.59	617	1.57

* Fish meal--%.

W.S.U. unpublished data (Berg).

Table 9.--Use of corn and wheat in laying rations and yearly egg production

	Grain		
	Corn	Wheat	Corn & wheat
Percent production	42.4	51.1	57.0
Eggs--hen-day basis	154	186	207
Eggs/hen finishing the year	196	228	225

Heuser, G. F., Poultry Sci. 22: 123.

Table 10.--Effect of different cereal grains on egg production

Grain in laying diet	Egg size	Shell thickness	Haugh unit	Eggs produced	Lbs. egg/ lb. feed
	g.	μ		lbs.	
Corn	56.7	392	76.6	73.4	0.294
Oats	56.5	390	76.5	40.7	0.162
Wheat	56.3	399	75.4	78.8	0.294
Mixed	56.5	396	76.0	72.2	0.273

Grininger and Scott, Poultry Sci. 33: 1217.

available, and not too much error would be introduced where total amount of an amino acid is used in calculating composition of diets.

Information on palatability, if we may use such a term, is not very great. However, some experiments have been conducted to determine preferences of birds for different grains. One was conducted at Washington State University approximately 25 years ago, in which turkeys were given a choice of a protein concentrate or balancer along with wheat, corn, oats, and barley. It was observed that wheat was consumed in greatest amount. Corn was second, oats third, and the turkeys ate practically none of the barley (Table 4). Some additional work was conducted in which the amount of protein concentrate or balancer offered was limited, and under these conditions the turkeys consumed a far greater proportion of their diet in the form of whole grain. Again, wheat was highly acceptable.

Table 11.--Effect of cereal grains on egg production and egg weight during first 6 weeks of lay

Week	Corn		Oats		Wheat		Barley		Milo	
	Av. egg wt.	Prod.	Av. egg wt.	Prod.	Av. egg wt.	Prod.	Av. egg wt.	Prod.	Av. egg wt.	Prod.
	g.	%	g.	%	g.	%	g.	%	g.	%
1	40.4	8.5	39.9	11.3	40.4	6.7	41.8	9.7	40.9	22.0
2	43.2	19.0	43.5	27.0	42.8	16.5	41.9	26.9	41.7	46.2
3	45.2	31.4	45.0	45.2	44.8	35.6	43.5	43.8	45.2	46.8
4	46.7	47.4	46.0	58.4	45.7	53.7	44.8	50.7	45.7	54.1
5	48.1	61.0	46.5	65.6	46.8	64.3	46.3	61.5	46.9	64.3
6	49.1	65.1	47.2	66.5	48.2	73.4	46.9	65.7	47.4	70.0

W.S.U. Report, June, 1959, pp.189.

Table 12.--Influence of cereal grains with and without corn oil in the diet on the average egg production and egg weight of SCWL chickens maintained in colony cages

Week	Corn		Corn + 5% corn oil		Wheat		Wheat + 5% corn oil	
	Egg Prod.	Av. egg wt.	Egg prod.	Av. egg wt.	Egg prod.	Av. egg wt.	Egg prod.	Av. egg wt.
	%	g.	%	g.	%	g.	%	g.
1	3.03	38.0	3.15	40.7	0	39.6	2.4	39.3
2	10.8	41.0	9.42	41.5	8.9	40.5	12.7	40.9
3	23.0	43.8	24.4	44.4	18.8	43.4	23.7	43.9
4	38.4	44.0	38.1	45.5	28.6	44.1	41.9	45.5
5	56.7	45.0	55.7	46.6	45.5	45.8	55.5	47.5
6	65.6	47.1	71.7	47.9	55.4	46.5	65.3	48.8
7	71.1	47.9	77.1	48.8	56.3	47.3	69.3	49.5
8	69.3	48.7	76.1	49.5	50.9	48.3	66.1	50.5

W.S.U. Reports, 1960, p. 50.

Table 13.--Effect of water treating and enzyme supplements on nutritional value of grains for turkey poults

Grain	Water treatment	Av. wt. 3 wks.	Feed/gain	Enzyme suppl.	Av. wt. 27 days	Feed/gain
		g.			g.	
Corn	No	419	1.36	No	646	1.47
Corn	--	--	--	Yes	687	1.49
Barley	No	292	1.64	No	433	1.78
Barley	Yes	408	1.52	Yes	566	1.64
Wheat	No	398	1.42	No	612	1.54
Wheat	Yes	437	1.40	Yes	632	1.50

Fry *et al.*, Poultry Sci. 37: 372.

When wheat is used as the cereal in rations for young chicks, it is important to know the type used, in terms of protein content, and to make adjustments in formulation to obtain the most satisfactory results. In some experiments at the University of British Columbia (Table 5), it was found that protein had to be increased to a higher dietary level when high-protein wheats were used. Undoubtedly some of the essential amino acids become limiting when wheat protein constitutes too high a proportion of the total dietary protein. It was also interesting to see that high-protein wheats tended to give somewhat

Table 14.--Effect of supplements and treatments of wheat and wheat by-products on chick growth

Diet or supplement	Av. chick wt.--3 wks.	Feed/gain	Screen score
	g.		
Corn	263	1.60	0
Wheat	230	1.76	0
Wheat + fungal enzyme	240	1.74	1/3
Water treated wheat	249	1.65	0
Autoclaved wheat	239	1.66	0
Autoclaved wheat + fungal enzyme	261	1.69	0
Acid-hydrolyzed wheat	251	1.80	5
Acid-hydrolyzed wheat + fungal enzyme	245	1.86	3-1/3
Wheat mixed feed	186	2.46	2/3
Wheat mixed feed + fungal enzyme	193	2.49	1/3
Water-treated wheat mixed feed	222	2.10	1
Autoclaved-wheat mixed feed	203	2.43	1/3
Autoclaved-wheat mixed feed + fungal enzyme	214	2.26	1-1/3
Acid-hydrolyzed wheat mixed feed	166	2.72	5
Acid-hydrolyzed wheat mixed feed + fungal amylase	198	2.37	5

W.S.U. unpublished data.

lower feed efficiency at all three protein levels than the lower-protein wheats. When results of other work conducted in Canadian universities are considered, we discover difficulties in reconciling results obtained when wheat was compared with corn. At the University of Guelph (Ontario Agricultural College), studies have been conducted in which wheat was compared with corn (Tables 6 and 7). Growth of chicks was actually improved when corn was replaced by different levels of wheat, and feed efficiency was also improved, especially when fish solubles were included in the diets. Results in Table 7 were obtained with diets quite representative of commercial broiler rations. Whether ingredients in the basic diet which have not been used extensively in some of our studies on the West Coast account for similarity of results with corn and wheat cannot be determined.

We are currently trying to determine how the types of wheat we are now producing in Washington compare with corn and other grains in poultry feeds. From one experiment still in progress at our Western Washington Station under Dr. Berg, 4-week results are shown in Table 8. It is apparent that replacing corn in the broiler diet caused a drop in both chick growth and feed efficiency at 4 weeks. Adding increasing levels of fish meal singly or in combination did not eliminate the differences when corn constituted less than half the cereal grain. On a competitive basis, the type of differences observed would mean that wheat must sell at lower price than corn if it is used extensively in broiler production. All diets reported in Table 8 contained 22% protein, 3% added tallow, and were fed in crumbled form. Differences in protein levels and physical form should not have been important factors in the type of differences obtained.

Table 15.--Responses of varieties of wheat to fungal amylase supplements and to water treatment

Diet or supplement	Av. wt. 3 wks.	Feed efficiency
	g.	
Corn	232	1.83
Barley	190	1.99
Barley + fungal amylase	225**	1.82
Water treated barley	238**	1.75
Burt	213	1.77
Burt + fungal amylase	234**	1.68
Water treated Burt	247**	1.51
Golden	208	1.76
Golden + fungal amylase	223	1.80
Water treated Golden	236*	1.67
Requa	204	1.83
Requa + fungal amylase	231*	1.72
Water treated Requa	241**	1.65
Idead	219	1.77
Idead + fungal amylase	217	1.71
Water treated Idead	256**	1.60
Baart	215	1.80
Baart + fungal amylase	226	1.76
Water treated Baart	254**	1.67
Rio	216	1.78
Rio + fungal amylase	217	1.73
Water treated Rio	256**	1.66
Omar	207	1.79
Omar + fungal amylase	230*	1.73
Water treated Omar	239**	1.65
Marfed	235	1.67
Marfed + fungal amylase	227	1.69
Water treated Marfed	240	1.63

* Significantly and **highly significantly different from its own untreated sample, as determined by analysis of variance and Duncan's multiple range test. W.S.U. Reports, 1959, p.292.

Wheat has been used extensively for laying hens and for a long period wheat was essentially the only cereal used in the Pacific Northwest in the production of all types of poultry. This period was before price supports made it uneconomical to use wheat. Dr. Heuser of Cornell University reported about 25 years ago that wheat supported better egg production than corn when used as the only cereal (Table 9). I might point out that the indicated superiority of wheat has not been confirmed in other studies but that results showing equivalent value have been obtained.

Another experiment with cereal grains in laying rations was reported from the University of Illinois (Table 10). Egg size, shell thickness, and egg quality (Haugh units) were essentially the same for all grains compared. Egg production was reported as pounds produced during the experiment. In these terms, superiority of wheat was indicated, which would agree with results obtained by Heuser. However, in pounds of eggs produced per pound of feed

Table 16.--Effect of cereal grains on response of turkeys to enzyme and antibiotic supplements

Grain in diet	Supplement	Av. 4 wk. wt.	Gain/feed
		g.	
Corn	None	563	0.59
	Oleandomycin (O)	574	0.64
	Enzyme (E)	561	0.62
	O + E	575	0.64
Wheat	None	549	0.61
	O	563	0.63
	E	552	0.61
	O + E	552	0.62
	Bacitracin	562	0.64
	Streptomycin	567	0.64
Barley	None	474	0.53
	O	537	0.60
	E	540	0.60
	O + E	589	0.64

W.S.U. unpublished data.

Table 17.--Use of different types of diets in growing replacement pullets

Ingredient	Diet Number 1	2	3	4
Ground corn	32.8	42.3	32.8	17.3
Milo	32.8	32.8	21.5	--
Peas	21.5	--	--	--
Split pea byproduct	--	17.0	--	--
Pearled barley byproduct	--	--	38.0	--
Wheat mixed feed	--	--	--	75.0
Soybean meal (50%)	5.0	--	--	--
Fish meal	2.5	2.5	2.5	2.5
Alfalfa dehydrated (17%)	2.5	2.5	2.5	2.5
Dicalcium phosphate (Dynaphos)	1.0	1.0	1.0	--
Ground Limestone	1.0	1.0	1.0	2.0
Salt	0.4	0.4	0.4	0.4
Trace mineral mix[1/]	0.05	0.05	0.05	0.05
Chicken developer, vitamin premix[2/]	0.25	0.25	0.25	0.25
Average pullet weight at 20 weeks (lbs.)	3.10	3.16	3.18	3.10
Average feed consumption (lbs.)	11.9	11.8	11.6	14.6

[1/]Supplies the following in ppm: Mn, 50.0; Fe, 50.0; Cu, 5.0; Co, 0.5; I, 1.5; Zn, 50.0.

[2/]Supplies the following per pound of feed: vitamin A,2,000 I.U.; vitamin D_3, 500 I.U.; riboflavin, 1 mg; Santoquin, 29 mg.

W.S.U. unpublished data.

consumed, corn and wheat gave identical values. This would indicate that if production rate had been the same, the ration containing wheat would have been somewhat less efficient than the one containing corn.

We have been concerned at Washington State with factors that influence egg size and with different grains as contributing factors. We observed a number of years ago that certain types of feed cause hens to lay unusually small eggs, and that addition of ingredients such as cereal grain and soybean meal to the diet caused a pronounced increase in egg size. We then were interested in whether the increase in egg size, which takes place just after hens start laying, could be accelerated by different cereal grains. Table 11 shows the effects of five grains on change in egg size during the first six weeks of egg production. It appears that corn and wheat had just about the same effect, with corn possibly causing a slightly more rapid increase. Oats, barley and milo all three gave slower rate of increase in size.

In another study (Table 12) corn oil, which is rich in linoleic acid, was added to a laying ration containing either corn or wheat. Again, the rate of change in egg size during 8 weeks was essentially the same for rations containing either corn or wheat. The addition of corn oil to both rations caused hens to lay somewhat larger eggs than without corn oil.

When we discovered a number of years ago that feeding value of barley could be greatly improved for young chicks or turkeys by either a water treatment or adding a crude enzyme supplement produced by fermentation, we soon extended these studies to other cereals. Wheat and its byproducts were studied under contract with the Western Utilization Research and Development Division of USDA. Generally we have found that corn is not improved by either water treatment or addition of enzyme supplements to the feed. In contrast, we have found that wheat is often improved. Results with turkey poults are presented in Table 13. The average weights show that water treating both barley and wheat gave significantly better results than we obtained with either one alone. In these studies wheat and its byproducts behaved more nearly like corn than barley although significant improvement was obtained in many cases (Tables 14 and 15). In the literature dealing with response to enzyme supplements, it is difficult to find a trial in which an antibiotic supplement was not used in the basal diet. Some antibiotics partially replace water treatment and enzyme supplementation (Table 16). This would perhaps account for much of the variation reported from one laboratory to another.

Since almost a third of all wheat milled for flour ends up as a milling byproduct, we have been interested in making more effective use of it in feeding animals. We have just recently completed an experiment in which some byproduct feeds were used as components of diets for replacement pullets (Table 17). Average weight of pullets at 20 weeks of age was unaffected when 75% of wheat mixed feed was used to replace most of the cereal grains and all of the supplementary protein materials except 2.5% fish meal.

Summary. The results of extensive experimentation would support the following conclusions: (1) Wheat is a highly acceptable grain for use in poultry production. (2) In many of the studies, slightly lower growth and feed efficiency are obtained when wheat is substituted for corn. (3) Composition of different cereal grains is amazingly similar, with some slight differences in available energy and fat content (the amount of essential fatty acids supplied by corn might possibly account for its slight superiority). (4) Many varieties of wheat are improved in nutritional value by addition of either an enzyme

supplement to the diet or water-treating the wheat. (5) Cereal grain component of the diet markedly influences the growth response to antibiotic supplements. In this respect, wheat resembles corn in that it does not cause an increased response to antibiotics. (6) Wheat milling byproducts can be effectively utilized in poultry production to a much greater extent than is currently being done.

UTILIZATION OF LONG EXTRACTION WHEAT FLOURS FOR PRODUCTION OF GLUTEN AND STARCH BY THE BATTER PROCESS

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The manufacture of gluten and starch by wet processing utilizes large amounts of second clear flours from the dry milling of wheat to flour. Second clear flour is the most desirable milling fraction for this purpose because of its high gluten protein and low price. In most cases wet processors contract for clears to ensure a constant supply. However scarcities of second clears occur, forcing processors to use higher priced flours, often with lower protein content. Several comments were made last year at the conference in Peoria, regarding a shortage of clears. An investigation was undertaken to find substitute raw material equally satisfactory.

A series of flours of various extractions was prepared by milling a blend of three hard red winter wheats containing 14.9% protein (dry basis). The blend was milled by a standard experimental procedure to obtain a straight-grade flour of about 72% extraction. Flours of 76, 80, 85, 91, and 96% extractions were made by remilling the offal fractions and blending the low-grade with the straight flours. Two commercial second clear flours were used for controls.

These flours were processed in the pilot plant by a modification of the continuous batter process developed at the Northern Laboratory (Cereal Chem. 35(6): 449-57, 1958). This modification involved batch mixing the batter rather than continuous mixing, and allowed use of smaller batches of flours. In a Hobart mixer, 1 part of flour and 1.3 parts of water at 122° F. (50° C.) were mixed until a smooth, elastic batter was obtained, usually after 15 minutes. Then 1.4 parts of cold water were added to wash starch from the gluten. Gluten was separated from the starch on a Rotex shaker, fitted with a 150-mesh screen, and then washed by pumping it with added water to a second shaker screen. After repetition of washing, the final gluten was cut into small pieces, placed on trays, and dried in a vacuum tray drier, operated at 130° F. (55° C.) and 29 in. Hg vacuum.

Crude starch slurry from the screening operations was passed over a 17XXX silk bolting cloth to remove any bran or small pieces of gluten that might interfere with subsequent starch recovery. The fraction recovered on the silk has been designated "screenings." After the clean, crude starch slurry settled overnight, the supernatant water was removed and the specific gravity of the slurry adjusted to 3.5° Bé at 60° F. (15.6° C.) preparatory for tabling. Tabling was carried out on a 40-ft. aluminum table, pitched at 1 in. for the

Table 1.--Analyses of original flours and of glutens and starches separated by the batter process (moisture-free basis)

Flour used	Original flour		Gluten		Prime starch	Tailing starch
	Protein	Ash	Protein	Ash	protein	protein
	%	%	%	%	%	%
Extraction						
72%	13.7	0.54	74.5	0.43	0.24	2.53
76%	14.1	0.67	73.5	0.63	0.24	2.51
80%	14.3	0.78	72.2	0.58	0.24	3.86
85%	14.6	1.04	71.5	1.08	0.27	3.17
91%	15.4	1.55	71.9	1.39	0.31	5.59
96%	14.9	1.66	67.6	3.64	0.30	5.87
Commercial 2nd clear	18.7	1.32	73.7	0.94	0.43	4.86
Commercial 2nd clear	17.3	1.17	69.1	1.33	0.36	3.67

Table 2.--Cost analysis for dry and wet milling of wheats

	Percent extraction						Com. 2nd clear	Com. 2nd clear
	72	76	80	85	90	95		
Products per bu. wheat, or 100 lbs. of 2nd clear, lbs.:								
Gluten 1/	5.45	6.30	6.90	7.35	7.48	7.52	17.3	17.0
Prime starch 2/	24.30	24.90	25.10	24.90	24.40	23.60	44.7	46.0
Tailing starch 2/	6.25	7.10	8.00	9.25	10.80	12.70	19.2	17.0
Feed 3/	17.50	14.40	12.20	10.20	8.70	7.50	1.9	3.2
Value of products, $	3.376	3.605	3.765	3.880	3.916	3.935	7.808	7.758
Total production cost, $	3.264	3.338	3.399	3.461	3.506	3.547	6.665	6.665
Operating margin/bu wheat, $	0.112	0.267	0.366	0.419	0.410	0.388	--	--
Operating margin/cwt. flour, $	0.259	0.586	0.763	0.822	0.759	0.681	1.143	1.093

1/ Gluten at 75% protein (d.b.) and 6% moisture.

2/ Starches at 12% moisture.

3/ Feed at 15% moisture.

full length. "Prime starch" was removed from the table, filtered, and dried; "tailing starch" was collected, centrifuged, and dried. All process waters were combined, concentrated, and dried to give a fraction called "dry solubles." In general, total recovery of products was 95+%.

Table 1 lists analytical values for original flours and for the glutens and starches recovered. The products from the batter process are gluten, prime starch, tailing starch, screenings, and dry solubles. Each varies in value as a usable product commercially. Gluten and prime starch are main products with tailing starch next. Screenings are usually suitable for use as a feed product, and in most flour plants the soluble fraction is discarded as waste.

Gluten was recovered from each of the tested flours with little or no processing difficulties. Protein recovered in the gluten fraction was highest from the 80% extraction flour but acceptable at all levels. Protein content of the gluten decreased from 74.5% at 72% extraction to 71.9% at 91% extraction, and then dropped to 67.6% at 96% extraction. Pup bake tests showed that loaf volume of the gluten increased as flour extraction increased up to 91%. Total quality scores decreased slightly, with poorer total scores from glutens at the highest extractions due to lower scores in texture, grain, and crumb color. Processing results and gluten quality tests indicated that flours as high as 85% extraction could be used as raw materials for separating vital gluten products suitable for the baking industry.

High-quality prime starch was recovered from each of the flours, but the quantity of prime starch recovered decreased as flour extraction increased, with a corresponding increase in the tailing starch fraction. Undoubtedly prime starch recovery would be considerably better on an industrial scale through use of equipment especially built for this purpose. As expected, the screenings fraction--consisting of bran, cell wall material, and some gluten particles--increased as level of flour extraction increased. This fraction could well serve as a feed.

In industrial practice the soluble fraction (about 2% solids concentration) from wet processing wheat flour is customarily discarded even though it might amount to as much as 10% of the flour solids. In our study this fraction was concentrated and dried. In general, the chemical analyses of the dry solubles from the different extraction flours were somewhat similar. With protein content about 12% and sugar averaging about 15%, this fraction has potential application as a nutrient in foods, feeds, and fermentation media or as a source of globulins and albumins.

A cost analysis on the overall process from the milling of the wheat to the final dried products (Table 2) indicated an increasing processing cost as flour extraction level increased. A corresponding increase in product value was also noted from 72% to 85% extractions. Calculated operating margin per bushel of wheat was 11 cents at 72% extraction, increasing to a maximum of 42 cents at 85% and then diminishing as the processing cost increased at a greater rate than product value to 39 cents at 96% extraction. In comparing the use of 85% extraction flour in the batter process, with commercial second clear flour selling at $4.50/cwt., wheat should sell at about $2.10 per bushel to be equally profitable on he basis of flour processed.

ANALYSIS OF ECONOMIC STATUS OF AIR CLASSIFICATION IN THE MILLING INDUSTRY

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During the past decade there has been a great deal of interest in, and much research devoted to, air classifying wheat flour. There has also been concern as to its ultimate impact on markets. I should like first to review some of the things air classification can do. We will then examine its economics with soft and hard wheat flours in model situations. Lastly, we shall consider some obvious implications of the technique.

The flour miller is interested, because the technique can give him a measure of independence from his wheat supply. With conventional milling techniques the miller depends on the character of wheat he mills to attain desired properties in flour. A good bread flour requires selection and blending of wheats having a high percentage of strong protein. Seasonal, geographic and varietal differences in the quantity and quality of protein complicate this problem, which is more difficult in some areas than in others.

The miller of soft wheat has a similar problem. Cake and pastry flours require a lower percentage of protein and a more mellow gluten. Other bakery products require special properties in flours. The wheat needed to achieve these properties is not always economically available.

Air classification permits separation of wheat flour into fractions varying widely in composition of protein and starch and in baking quality. These fractions can be applied to uses for which they are best suited or they can be blended with other flours to achieve a range of properties. Thus, within limits, air classification permits the miller to tailor-make flours. It also permits production of more uniform flour from lot to lot and season to season. Protein level and flour granularity, both important, can be controlled. The technique also reduces the need for old-crop wheat to smooth out the transition to a new crop.

The principal function of air classification of soft wheat is to adjust the protein level in cake, cookie, and cracker flours. It permits use of nearby wheats to produce special flours. Also, it is reported to increase the yield of bakery products per pound of flour, extend their shelf life, and improve grain, texture, and handling characteristics. In hard wheat areas, the principal value is in upgrading low-protein wheat for bread flour production and to produce cake and pastry flours from this type wheat. It aids in overcoming variations in wheat quality and enables more uniform flour from season to season.

Since the first announcement of its use on wheat flour, air classification has had gradual acceptance by flour milling and baking industries. Most of our larger mills have done extensive research on the technique. Ten to 12 mills are now using it for the production of around 3% of total flour output.

Because air classification permits concentration of protein and starch fractions at low cost compared to wet-milling processes, it has been proposed for industrial flour products. Feasibility hinges on the premise that premium value of the high-protein fraction in food uses and savings on wheat procurement costs would permit a low-protein "byproduct" fraction to compete in industrial uses with starches from other sources. This assumes that in certain milling situations there will be an excess of low-protein flours over that absorbed in food channels. Considerable emphasis in work at USDA's Northern Regional Research Laboratory has been directed toward low-protein fractions for industrial use.

Table 1.--Production possibilities for soft red winter wheat

	Value	Conventional mill		With air classification			
	per			A		B	
Product	cwt.	Pounds	Value	Pounds	Value	Pounds	Value
Millfeed	$1.80	38	$0.68	38	$0.68	38	$0.68
Clears	4.30	10	0.43	10	0.43	10	0.43
Cracker and biscuit flour	5.40	40	2.16	35	1.89	12	0.65
Cake flour	6.00	50	3.00	45	2.70	30	1.80
High-protein flour	8.50	--	--	10	0.85	18	1.53
Industrial flour	4.25	--	--	--	--	30	1.27
Total		138	$6.27	138	$6.55	138	$6.36

Let us now examine the economics of air classification in model situations. Table 1 shows a range of possibilities with roller-mill techniques as well as fine grinding and air classification on soft red winter wheat. These possibilities are greatly simplified. The prices shown, with the exception of the high-protein and industrial-flour fractions, are about average for 1960-63 on the Chicago market. Prices used for the high-protein and industrial-flour fractions are our estimates. The products represent those for a typical soft-wheat mill.

Output A represents use of fine grinding and air classification to reduce protein in a soft-wheat cake flour. A high-protein fraction is obtained which is useful in fortifying doughs for yeast-raised bread products. Although removal of this fraction may enhance the value of cake flour, we have not claimed a premium for it.

Output B represents possible products from the application of additional fine grinding and air classification. More of the high-protein fraction has been removed and an industrial-starch fraction has been isolated. This latter fraction has special interest because its use for industrial purposes would extend the market for wheat. You will note that we have estimated the price of the industrial-starch fraction to be substantially below the price of cake flour.

Comparative returns from the three possibilities are shown in Table 2. Wheat costs are based on average prices for soft wheat on the Chicago market for the period 1960-63. Processing costs are based on estimates and do not include marketing costs or general administrative expenses. Thus, the margin indicated here would cover these costs as well as profit.

Table 2.--Comparative returns from different production possibilities for soft red winter wheat

Item	Conventional mill	With air classification A	With air classification B
Production value:	$6.27	$6.55	$6.36
Costs:			
Wheat (2.3 bu. @ $2.06)	4.74	4.74	4.74
Processing	0.46	0.55	0.61
Total	$5.20	$5.29	$5.35
Margin:			
Dollars	$1.07	$1.26	$1.01
Percent	17	19	16

Under the assumptions used, Output A using air classification would be the most profitable and Output B which includes the industrial-starch fraction would be the least profitable. Depending on the supply situation, air classification may allow the miller to make some savings on wheat procurement. For example, soft wheat millers in certain locations have been able to make small savings by substitution of soft red winter for white wheat. Such savings would of course vary with season and mill location.

Now let us turn to the economics of air classifying hard red winter wheat. This class has accounted for around half of total production and 75 to 80% of annual carryover in recent years. Air classification seems to offer distinct advantages. Table 3 shows the average protein level of wheat received on several terminal markets in the hard red winter and hard red spring areas. These data are based on samples from carlot receipts during the first 90 days of the season. With conventional milling a good bread flour requires wheat

Table 3.--Average protein content of commercial carlot receipts of wheat

Class of wheat and market	Crop year 1957	1958	1959	1960	1961	5-year average
	%	%	%	%	%	%
Hard red winter:						
Enid	12.4	12.2	12.0	12.0	10.9	11.9
Kansas City	13.0	11.3	11.6	10.8	10.2	11.4
Omaha	11.4	11.6	11.7	11.9	10.3	11.4
Wichita	12.4	12.3	12.6	12.0	10.6	12.0
Hard red spring:						
Great Falls	15.0	14.3	14.9	15.8	15.7	15.1
Minneapolis	14.1	13.6	14.4	14.3	14.2	14.1

containing 12 to 13% protein. We can see that a substantial part of hard red winter wheat receipts would not meet this requirement. Of course, some of this wheat is used for family flours which require less protein. Also, the considerable surplus of this class permits mills to be selective.

With air classification, a miller can take wheat containing 11 to 11.5% protein, remove a low-protein fraction suitable for cake and general-purpose flours, and use the remainder for bread flour. Thus, air classification tends to make protein level less important in making bread and cake flours. Our

information indicates, however, that protein level becomes less important but good quality is still needed.

The economic advantage of air classifying hard red winter wheat comes from: (1) savings on protein premiums, (2) the generally higher price of cake flour compared to bread flour, and (3) possibly a premium for the air-classified over conventionally milled bread flour. Possible savings on protein premiums are illustrated in Table 4, which shows prices over the past 4 years of wheat at two protein levels on the Kansas City and Minneapolis markets. Premiums

Table 4.--Prices for wheat of different protein levels

Market and crop year	Price per bushel		Difference	
	11.5% protein	12.5% protein	Per bushel	Per cwt. flour
Kansas City, HRW				
1960	$1.98	$2.05	$0.07	$0.18
1961	2.12	2.20	0.08	0.20
1962	2.24	2.36	0.12	0.30
1963	2.14	2.18	0.04	0.10
Average	$2.12	$2.20	$0.08	$0.20
Minneapolis, HRS	12% protein	13% protein		
1960	$2.12	$2.14	$0.02	$0.05
1961	2.32	2.34	0.02	0.05
1962	2.38	2.41	0.03	0.08
1963	2.26	2.27	0.01	0.03
Average	$2.27	$2.29	$0.02	$0.05

were much higher at Kansas City than at Minneapolis. Total savings possible by substituting an 11.5% for 12.5% protein wheat on the Kansas City market would be $0.20 per 100 pounds of standard patent bread flour, compared with an average of $0.05 on the Minneapolis market. This would indicate that air classification of spring wheat would be much less attractive than of hard winter wheat.

As you know, there are two kinds of protein premiums on wheat. One is illustrated in Table 4 and is based on level of protein. The other is based on protein quality, illustrated in Table 5. These data show the average spread in price of wheat at different protein levels on the Kansas City and Minneapolis markets. The spread is due primarily to differences in baking quality--the better baking quality commanding the higher price. For hard red winter there is a marked increase in price as protein level increases. Note also that the spread is much greater on hard red winter wheat than on hard red spring. Taking advantage of this spread would require substitution of a poor-quality protein wheat for good quality. Our information indicates that air classification would not permit such substitutions.

A somewhat analogous situation would exist in an area which "imports" strong wheats for blending with local wheats at an additional cost in freight. Air classification would permit more effective use of the good protein available locally and thus should permit some savings on procurement costs. However, in the absence of suitable protein in the local area, air classification would not eliminate the need for "imported" wheat.

Table 5.--Average price spread in cents per bushel for wheat at various protein levels

Market and percent protein	Crop year 1960	1961	1962	1963
Kansas City, HRW				
Ord.	3	0	3	4
11	3	1	3	4
12	6	8	10	8
13	11	10	12	10
14	12	10	14	12
Minneapolis, HRS				
Ord.	1	3	1	2
11	1	1	3	2
12	1	1	3	3
13	1	3	2	2
14	1	3	3	3
15	4	2	1	2
16	2	3	5	4
17	3	4	4	3

Another advantage to air classification of hard winter wheat results from the higher price for cake flour, compared with bread flour. These prices for the Kansas City, St. Louis, and Chicago markets are shown in Table 6. Prices for both cake and bread flours are reported for the Chicago market and show an average premium for cake flour over the past 4 years of about $0.30 per hundredweight. The price of cake flour at St. Louis averaged over a dollar more than bread flour at Kansas City.

Table 6.--Comparison of prices for cake and bread flours

Crop year	Cake flour price per cwt.	Standard patent bread flour price per cwt.
	St. Louis	Kansas City
1960	$6.38	$5.36
1961	6.56	5.56
1962	7.06	5.84
1963	6.90	5.45
Average	$6.72	$5.55
	Chicago	Chicago
1960	$6.00	$5.54
1961	5.98	5.89
1962	6.20	6.09
1963	6.24	5.75
Average	$6.10	$5.81

For the hard wheat miller able to produce a cake flour comparable to that from soft wheat, this would be an attractive outlet. However, it must be recognized that the market for cake and pastry flour in the hard wheat area is limited. Large-scale production could seriously depress market prices. The major markets for flour lie to the east and far west--areas in which soft wheats have a competitive advantage.

Let us now examine the economics of air classifiying hard red winter wheat flour in a model situation. A range of production possibilities is given in Table 7. Using conventional milling techniques, it is assumed an 11.7% protein standard patent flour is produced from a 12.5% protein wheat blend. This is typical of a conventional mill setup. Flour prices are average for the Kansas City market over the past 4 years. Production possibility A assumes use of fine grinding and air classification to produce an 11.7% protein bread flour and an 8% protein cake flour from 11.5% protein wheat. The yields are based on results of air classification work at the Northern Laboratory. Output B assumes application of additional fine grinding and air classification to increase yield of bread flour and to obtain a fraction sufficiently low in protein for industrial use. To date, it has not been technically possible to achieve this industrial-flour fraction from hard wheat. The assumption was made on the basis that if the economics looked sufficiently promising it may be possible through research to overcome the technical problems involved.

Table 7.--Production possibilities for hard red winter wheat

Product	Value per cwt.	Conventional mill		With air classification			
				A		B	
		Pounds	Value	Pounds	Value	Pounds	Value
Millfeed	$1.80	41	$0.74	41	$0.74	41	$0.74
Clears	4.20	9	0.38	9	0.38	9	0.38
Bread flour	5.60	100	5.60	68	3.81	88	4.93
Cake flour	6.00	--	--	32	1.92	--	--
Industrial flour	4.25	--	--	--	--	12	0.51
Total		150	$6.72	150	$6.85	150	$6.56

Prospective returns from the 3 possibilities are compared in Table 8. Wheat costs for the conventional mill are based on average prices for 12.5% protein wheat at Kansas City for the period 1960-63. Wheat costs with air classification are for an 11.5% protein wheat. Processing costs are estimates made at the Northern Laboratory for hard wheat. As indicated earlier, they do not cover marketing nor general administrative expenses. The combination

Table 8.--Comparative returns from different production possibilities for hard red winter wheat

Item	Conventional mill	With air classification	
		A	B
Product value:	$6.72	$6.85	$6.56
Costs:			
Wheat	5.50	5.30	5.30
Processing	0.50	0.60	0.67
Total	$6.00	$5.90	$5.97
Margin:			
Dollars	$0.72	$0.95	$0.59
Percent	11	14	9

produced under A results in the highest total product value as well as the lowest total costs. Output B, which includes the industrial-flour fraction, would be least profitable.

From examples for both soft and hard wheats, it is evident that a miller would not gain from producing an industrial-starch fraction if he could sell his entire output for food. However, if he had saturated his market for cake and other low-protein flour but had additional demand for high-protein flours, along with unused capacity, it might be profitable for him to produce the industrial flour. This would be true if revenue from the added output was above the mill's marginal cost--the extra cost of producing the additional flour. Proximity to industrial outlets would be a prerequisite.

These model situations show that air classification can be advantageous to the miller. It would be most advantageous where its use to improve and control flour quality also would permit savings in procurement. There appears to be a segment of the industry that could benefit. On this basis, we can expect a gradual increase in use as mills adapt the technique to their requirements. Of utmost importance is a balance between output of various fractions and demand. An excess supply of any one fraction could quickly erase any advantage.

Some shifts in the movements of wheat and flour to market can be expected from use of air classification. These shifts, however, are not likely to be pronounced, since movements of wheat already vary considerably from year to year. The effect on flour movements, on the other hand, may be more noticeable--particularly the displacement of soft wheat flours by low-protein hard wheat flours in certain areas.

Because air classification makes the protein level of wheat less important, its increased use may tend to lower premiums based on protein level. However, it should not affect premiums based on protein quality. In fact, some experts feel that protein quality may become even more important in the future.

FLOUR AGGLOMERATION

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The US standards of identity describe flour as follows: "flour, white flour, wheat flour, plain flour is a food prepared by grinding and bolting _ clean wheat other than durum wheat and red durum wheat" and is of such character that "one of the cloths through which the flour is bolted has openings not larger than those of the woven cloth designated '149 Micron (100)' in Table 1 of 'Standard Specifications for Sieves, published March 1, 1940, in the L. C. 584 of the US Department of Commerce, National Bureau of Standards.'" In the dictionary, agglomeration is defined as: (1) the action or process of collecting in a mass: (2) an indiscriminately formed mass: a cluster of disparate elements, disparate meaning unequal or dissimilar. In brief, agglomerate means to gather into a cluster; to collect or come together in a mass.

With these definitions in mind, it might be well to consider flour agglomeration in present flour milling procedure. If one considers the present-day concept of flour as derived from wheat and composed of random-sized particles from about 1 to 2 microns up to 150 microns in size; and that some of

the particles are composed of starch granules embedded in a protein matrix which is sometimes called a flour cell; and if one looks at the process of milling comprising the steps of tempering and gradual reduction, etc., I could say somewhat facetiously that flour milling is, in essence, a de-agglomeration process.

In 1915, Vernon (8) described his attempts to develop an easily wettable wheat flour. In his patent he states that "the new product is made by bringing drops of water of suitable size containing, if desired, dissolved or suspended matter, into direct contact with a stream of the cereal flour, so that the drops are immediately surrounded with flour, thereby forming spherical masses, consisting of flour and water, the size of which depends on the size of the drops. These masses are then dried, the duration and temperature of the drying operation depending on whether it is desired to effect certain changes in the flour by treatments which are commonly known as conditioning or maturing." Other patents on agglomerating food products were granted to Gidlow and Mills (5), Prater (7), Baker (1), and Hair (6). US Patent applications on the Carnation process are now pending.

In discussing characteristics of agglomerated flours I would like to speak briefly about some of their physical, chemical, and baking properties as compared to nonagglomerated controls. In May 1964, the writer with Mr. Edward Brooks (2) presented a paper at the national meeting of American Association of Cereal Chemists on this subject. First, in regard to physical properties, flours agglomerated by the Carnation process were prepared essentially by the method described in the Canadian patent and have the following characteristics:

1. A marked change in granulation. From 10 to 70% of the product will be retained on the US-100 standard sieve, which, as we all know, is the present limitation of US flour standards. In the Carnation process, the amount of overs of a US-100 wire can be varied over the indicated range, depending upon processing conditions. In like fashion, the level can be carefully controlled, depending upon specifications.

2. There is also a marked difference in pourability of agglomerated flours as compared to the usual commercially milled flour. Pourability can be measured by various techniques, but one of the most obvious is flowability from a pour-spout package without agitation.

3. Wettability is another important characteristic. Well agglomerated flours can be made which will sink instantly when allowed to pour on still water. Others can be made which may require a few seconds to a minute before they sink completely. Nonagglomerated flours by contrast are poorly wetted and will not sink in water even after periods of 10 minutes or even longer.

4. In addition there is of course the change in density. A non-sifted all-purpose family flour will range in density from 130 to 140 grams for a household cup (240 ml.) and when sifted can have about 116 grams per cup. Cake and bread flours also show a difference in density between non-sifted and sifted products. Agglomerated flours can easily be made to equal the cup weight of sifted flours. In our process, it is possible to produce densities as low as 70 grams per household cup, which is approximately a 50% reduction from the original non-sifted flour. The low density in agglomerated flours is of course subject to an increase due to packaging and handling and this increase can have marked importance. It is possible by selected processing conditions, however, to build in considerable resistance to crushing and

increase in density. The package is also important in change in density which may occur in commercial channels.

5. Reduction in dustiness is also an advantage of agglomerated flours. Any of the common means of moving or dumping flour will clearly show that there is visibly less flour suspended in air from agglomerated than from regular flours. To the writer's knowledge, no explodability data on agglomerated flours have appeared as yet.

6. Storage tests in a variety of packages and under widely varied conditions have shown no significant difference between agglomerated and nonagglomerated controls. These data include, among others, moisture change, amylograph, farinograph and baking tests.

It has been found that there are no significant changes in the levels of protein and ash during flour agglomeration; likewise there are no significant changes in amylograph or farinograph characteristics with good agglomerating operations by our process. It is entirely possible to alter the amylograph and farinograph characteristics, but generally these are in the direction of poor baking quality. Claus and Brooks pointed out that with the Carnation process there is a slight but definite change in maltose values between agglomerated and nonagglomerated but that this approximately 10% reduction in maltose values has in our hands had no significant effect on baking properties of the three flours examined. Interestingly enough, data indicate that agglomerated flours tend to show a reduction in "starch damage" as compared to original nonagglomerated flour. To the writer, this observation indicates that agglomeration has brought together in a random aggregate some of the ruptured starch granules which have been bonded by the agglomerating process so that they do not show up in the conventional starch damage test.

In regard to baking characteristics there are probably some present who have had more experience than the speaker. Our own observations, plus those of outside laboratories, have clearly shown that agglomerated flours processed by our method have equal, if not in some cases slightly better, baking characteristics than nonagglomerated controls. This has been found true for not only all-purpose family flours but also for cake and bread flours. We have not had extensive experience with other agglomerated flours, but we do know that the type of processing involved in making the agglomerated flours has a significant effect on baking characteristics.

With this brief review of physical, chemical and baking characteristics of agglomerated flours I would now like to discuss processing. Obviously, I can only present information from patents and trade journals, and I'm reasonably confident that considerably more processing information has not been published than has been disclosed.

Gidlow and Mills (5) describe their process as one in which flour and sugar, in one example, is fluidized on a permeable supporting medium and a super-heated vapor-gas is allowed to travel through the bed of fluidized material, allowing super-heated vapor to heat the inner zone of the material. Then it is allowed to cool to its dew point and condense upon the surfaces of the moving particles, thus producing adhesive agglomerating films on this material, followed by a drying operation to reduce the finished product to the desired moisture content.

In the Canadian patent, Claus and Zimmerman (3) point out that flour without any additive is "processed by a conversion treatment in which the individual particles are moistened to an extent sufficient to render them sticky and adhesive. The sticky and adhesive flour particles are then caused to adhere together in the form of aggregates of random size and shape, but of a size substantially greater than the size of the individual particles making up the initial flour. Thereafter the material is subjected to a drying procedure to adjust the moisture content to a level less than 14%. The steps of moistening the particles of the initial flour to an extent sufficient to render them sticky and adhesive and the final drying steps are accomplished under such time-temperature conditions that the final aggregated product has not been changed either with respect to its quality, as measured by objective measurements, or by its usability from the initial starting flour."

Baker (1) in his patent discloses methods of agglomerating flour-containing food mixes which comprise uniformly moistening the particles of the mix with the finely atomized spray of water in amounts sufficient to increase the total content of the moisture of the mix solids to a level from about 5 to about 23 weight percent in a horizontal cylinder in a specified manner and then drying loosely aggregated free-flowing product at temperatures from about 50° F. to about 125° F.

Later Hair (6) added to the art of agglomeration by disclosing the method of agglomerating cake mixes comprising from about 25 to about 50% flour, plus shortening and sugar, in which the cake mix particles are contacted with a finely atomized spray of concentrated liquid sugar solution and agitating the mass of said particles in shallow bed under specified conditions to form free-flowing , loosely compacted aggregates without drying, and eventually yielding aggregates having a larger average particle size than the un-agglomerated particles.

M. W. Vincent (9) in the May 1964 issue of the American Miller and Processor discusses the Blaw-Knox process. He states that "when normal wheat flour is agglomerated, the material is fed through a pneumatic conveyor into a rotary feed valve for control of the powder rate to a small moistening chamber. The dry powder is introduced in a narrow stream across the upper diameter of the agglomerating section, and falls by gravity between two jet tubes through which a suitable agglomerating fluid is constantly ejected in a highly atomized form. As the powder passes through this zone, the particles are uniformly wetted on the outside and brought into intimate contact with each other by induced turbulence. In addition, the Instantizer tube is designed with a series of radial slots to which air at ambient temperature is fed to cause a vortexing motion. This arrangement not only causes further collision of the sticky particles, but also initiates a condensation of the moisture which was introduced at the top of the unit.

"Control of the air flow rate regulates the flow pattern and particle temperature. Leaving this section, the product is then dropped through an air heated chamber of small dimensions where surface evaporation is continued.

"The large clusters of agglomerated flour subsequently are discharged from the bottom of the unit directly on a conditioning conveyor belt where the material is allowed sufficient time for all particles to come to uniform moisture equilibrium. The conditioned material then is fed to a vibrating deck-type air-heated after-drier. In the final step, the agglomerated material is cooled and selectively screened as desired for packaging or storage.

"Since care must be taken to prevent denaturization of protein, careful control of the temperature and flow rates is important. Temperatures during the agglomeration of wheat flour are maintained between 120° to 130° F. and the retention time in the wetting zone is limited to no more than 45 seconds to 1 minute.

"By use of tempered air in the after-drying system, the product temperature also is maintained below 120° to 130° F. during the drying cycle for a total of an additional 3 to 4 minutes. The retention time in the entire system including the conditioning zone is approximately 6 to 9 minutes."

E. J. Gehrig (4) in the June 1964 issue of the American Miller and Processor discusses the Commercial Solids Treatment Corporation process in regard to space requirements, capacities, and cost of equipment but he does not discuss processing details.

I would now like to discuss a few marketing factors. As we all know convenience is important in new food products. This has been amply demonstrated, and many market studies have indicated that the consumer is willing to pay a higher price for convenience provided, of course, that it meets other definite critera such as good flavor, nutrition, etc. The writer makes no attempt to pose as an expert on marketing, but a brief review of factors involved might be helpful.

In the early days of instant nonfat dry milk, studies were made to determine what was needed to successfully market this new product. Size and type of package, quantities in a package, use of the product in the home, labeling for good usage, changes required in home use, how best to present this information, these and other problems faced the advertising and marketing people in introducing this new product.

It soon became apparent that one of the important characteristics was size and type of package. Regular nonfat dry milk had been marketed in times past in various packages, some of which were multi-wall bags of various sizes and shapes. Others had tried marketing in cartons. The new agglomerated nonfat dry milk readily indicated to marketing people the need for a pour spout, coupled with an easy re-closure. Consumer tests followed by test market operations soon indicated that certain sizes were definitely more preferred than others. Because nonfat dry milk has some very definite limitations on moisture gain, it was obvious that highly protective packaging would be involved which, of course, could not add any off flavors during commercial distribution.

All of these factors and others were studied and utilized in developing the product for marketing. With this background similar consumer tests were inaugurated with an agglomerated wheat flour product. Again, it was noted that the consumers had definite preferences as to type and size of package. In general, any carton is greatly superior to the standard flour sack. Complete avoidance of transfer from sack to cannister is, in itself, a marked advantage. It has been extremely gratifying to the writer to note that some of the flour millers currently marketing agglomerated flours have utilized some of these factors in presenting their products to consumers.

Future of Agglomerated Flours. To the best of my knowledge, five milling companies in the US have agglomerated and "instant blending" flours on the

market. In addition, three pancake mixes are agglomerated, "instant blending" or "easy pour," and two companies have instant self-rising flours (containing leavening and salt). All and probably others have appeared during the past two years. With this rapid development it is fairly safe to assume that other flour and flour-containing products will appear in the future.

I dropped and cracked my crystal ball many years ago, but I would like to indicate two areas which I believe will develop in the near future: (1) A marked improvement in quality of agglomerated flours. Every product, particularly new ones, have been improved by good research and development. These improvements have been in the form of lower costs, better yields, more uniformity, better performance, etc. I'm sure this will occur with agglomerated flours. (2) I believe that new agglomerated flours or flour-containing products will be directed towards specific segments of the market and will probably be highly functional and still have good profit margins. As one reflects on the many possibilities, one can only say that the flour milling industry is on the threshold of a new and exciting era.

Literature Cited

1. Baker, J. S., Process of agglomerating pulverulent flow-containing food mixes. US Patent No. 3,116,150 (December 31, 1963).
2. Claus, W. S., and Brooks, E. M., Cereal Science Today, in press.
3. Claus, W. S., and Zimmerman, H. K., Process for preparing a flour and flour-containing product and the product produced thereby. Canadian Patent No. 644,621 (July 10, 1962).
4. Gehrig, E. J., Agglomeration report to 1964 AOM conference. American Miller and Processor, June 1964, p. 26.
5. Gidlow, R. G., and Mills, A. D., Process and apparatus for agglomerating pulverulent materials. US Patent No. 2,995,773 (August 15, 1961).
6. Hair, E. R., Process for agglomerating culinary mixes. US Patent No. 3,135,612 (June 2, 1964).
7. Prater, A., et al., Aggregated dehydrated allium powder and process for making the same. US Patent No. 2,957,771 (October 25, 1960).
8. Vernon, T. T., Method of treating flour and product thereof. US Patent No. 1,155,977 (October 5, 1915).
9. Vincent, M. W., Test results pointing up new technique trends needed for growing production of agglomerated cereal products. American Miller and Processor, May 1964, p. 12.

PRESENT AND POTENTIAL MARKETS FOR BISCUITS, CRACKERS AND RELATED BAKED PRODUCTS

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First, may I express my appreciation for the kind invitation extended by Mr. Howard Morton to the biscuit and cracker industry to participate in this conference. This invitation comes as a real compliment to our industry. As a member, I should like to believe that the biscuit industry has gained stature in recent years. I should like to think, also, that our appearance here is a response to recognition of improvement in league standing. When I was a kid just starting in the biscuit business, it was often said that a cracker and cookie baker was a broken-down bread baker with his head kicked in. That remark may have had some truth. Even if true, a lot of "biscuit shooters" since that time have laughed all the way to the bank.

I will not bore you with statistics. A figure or two will put the biscuit industry into perspective. The total annual value of crackers, cookies and kindred products is now slightly higher than a billion dollars a year. Consumption in the United States is currently on a growing plateau. Latest figures show growth not quite in keeping with growth of population. We should be alert and energetic enough to be pushing consumption upward if we, as an industry, are to gather in a bigger share of the food dollar. Our technical people, our product developers, and our marketing experts have their work cut out for them. Some factors are working in our favor. Trends in eating habits point to increased popularity of convenience and ready-to-eat foods in all income classes.

A somewhat contrary factor is expressed by data recently published by Food Field Reporter from the 17th annual Consumer Expenditures Study for 1963. Those figures show a smaller increase in food-dollar spending between 1962 and 1963 than in any of five previous years. I guess that is the "plateau" I mentioned earlier. The study reveals that of the $1.47 billion increase, the spectacular sales were dietetic soft drinks (up 52%), canned soft drinks (up 16%) and nonfood products such as hair sprays and fixatives which increased by some 25%. Frankly, I can't get too disturbed by a report like this. People long ago acquired the habit of eating regularly and enjoying it.

The rate of achievement is, of course, our challenge in the food industry. We must support and substantiate our hopes and our optimism by a firm determination to improve our products. Whether we are growers or processors we must make sure of a constructive and consistent program of quality improvement. We must grow not only more wheat but a better quality of wheat. And we must grow the type the processor needs in his product-improvement program.

In the biscuit industry, as you well know, we use mostly soft wheat flours. So far as I know, nobody has ever been able to make an acceptable cracker out of a flour with hard wheat characteristics although the "trick" has been tried many times. Only from good strains of soft wheat can we expect to bake and deliver a cracker that is fit to eat. Given good strains of soft wheats in the several growing sections, I am sure that the milling industry,

with all of its strides forward in recent years, can deliver a maximum of uniform, high-quality flour. Improved milling and more careful wheat selection and blending backed by greater attention to precision quality control has already taken a lot of worry and trouble out of cracker baking. But even with all of these improvements, the best of flour millers cannot perform miracles. He simply can't make a good flour unless he can get the proper pure strain of soft wheat. Good work in this area is now underway, I am happy to report. The soft wheat improvement program now in full swing at Wooster, Ohio, is a most worthy effort. This program is closely watched and financially supported by the biscuit and cracker industry. Results come slowly, but it is certain that improvement will be the outcome, provided we get the necessary cooperation from growers.

In this connection, we also need assistance and understanding from our friends in the Department of Agriculture and from our representatives in Congress. Those folks who manage the government wheat programs have too often regarded wheat as wheat with little or no consideration of type or end-use. In this area our industry would be helped if cracker or biscuit type of wheat could be given an identifying name, just as durum designates the best wheat for macaroni and spaghetti products. I sincerely hope that we can get this idea started.

As we all well know, there is no surplus of soft wheat. Still, there are times when we hear of large lots being exported under the wheat program. Unless some distinction is recognized we shall face a serious shortage and a dire problem in our efforts to maintain and improve our products in our earnest endeavor to gain greater popularity for biscuit products. Inside our industry we have our work cut out for us. Companies are working hard and spending increased budgets on research and on product improvement as well as new products. Basic research is being accelerated. We want to know what actually happens to a tiny bit of cookie-shaped dough as it travels through the oven. After all these years in the old art of baking, surprisingly little is known in this area.

One company has recently installed a Raydine oven for experimental work on high-speed electronic baking. A breakthrough here could revolutionize the industry just as the process was turned upside down and inside out when the traveling oven replaced the old reel oven. Almost every company is working like crazy to develop new products and to discover new flavor combinations. This effort will continue, with even greater importance, to make new consumer friends. Here is one of the greatest opportunities for growth and to cash in on the potential market which I believe is like the legendary sleeping giant.

Just last month a small group of biscuit men from the United States traveled to several European countries to observe and study new methods and to look for new product possibilities. I was priviledged to tag along. This was a semi-official group sponsored by the Biscuit and Cracker Manufacturers' Association. We visited ten huge biscuit operations. We saw a lot of biscuits made. Everywhere we were received most royally and with red-carpet hospitality. These new friendships with European producers is certain to result in new products which will appear on the American market.

Another area is the development of new packaging materials, styles and designs. Improved keeping qualities with better packaging will mean longer

shelf-life. In the past few weeks there has actually appeared a cracker package that is easy to open and is reclosable, too. It took a long time to accomplish this feature, but someone finally made it.

I could go on and on with stories of the good work being done in the industry. Our trade industry is hard at work on technical training. The Biscuit Bakers Institute, with headquarters in Chicago, holds production training sessions annually. Special subject seminars are conducted. A well-prepared correspondence course, now available in English and Spanish, is becoming more popular with men and women in the industry. This association service is attracting interest and attention all over the free world. We are looking ahead optimistically to a greater market. Nation's Business in the November issue predicts that food spending will increase 42% by 1975. Cereal and bakery products are expected to rise 34% in the next 10 years. The biscuit industry is going to work hard to make that prediction come true. We are counting on the wheat growers and the milling industry to help us meet that goal. Give us good soft wheat milled to a uniform high standard and I guarantee we'll be a bigger customer of yours.

INDUSTRIAL REQUIREMENTS FOR BOXBOARD

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I'm here to talk about containerboard and corrugated cartons. Corrugated boxes have become so thoroughly a part of the American scene that we hardly notice them. Over 9 million tons of corrugated board were used to make corrugated boxes last year, and this material was valued at over $2 billion. The commonplace nature of corrugated boxes and the enormous quantity of materials that go into their manufacture interest us here, for these are the hallmarks of a big market, and provide the potential for a substantial increase in the industrial use of cereal grains.

There are two major classes of containerboard: corrugated board and solid fiber board. The former consists of linerboards, which form the smooth exterior surface, and a corrugated medium. Solid fiber board is a sandwich of linerboards with a chipboard filler. These components are manufactured separately for sale, in roll form, to converters or for use in other divisions of vertically integrated companies. (The corrugated box business is about 80% integrated.)

In the manufacture of containerboard, the components are combined with various adhesives. Solid fiber shipping container board is made by pasting linerboards to the chipboard filler. Corrugated board is made by passing the medium through a corrugating machine. The flutes are coated with an adhesive (usually starch or sodium silicate) and bonded to one liner and then, similarly, to another. In volume, corrugated board is over 100 times as important as solid fiber board.

The uses of corrugated board range from padding to shipping containers for heavy industrial equipment. Double-faced corrugated is the most common form, and it is used for a multitude of sizes and shapes of shipping containers. Boxes made from corrugated have good strength and cushioning characteristics, and they are far less expensive to buy, use, ship and dispose of than the containers they displaced, namely nailed or wirebound wooden containers. Containerboard can be made partially water resistant so that it can be used where the contents are damp, or where the contents need protection from water.

Production of containerboard since 1949 has risen a little over 5% per year, a rate slightly greater than the growth in our gross national product and nearly 3 times the rate of our population growth. At 10,400,000 tons, output represents slightly more than one-fourth of the total production of all grades of paper and paperboard, and is the largest of the many classes of paper and board produced in the US.

Users of corrugated shipping containers are found among virtually all of our manufacturing groups. Manufacturers of food and kindred products provide a market for over one-fourth of the fiber boxes produced. Although this use represents a smaller proportion of the total market than it did in the early 1950's, the total volume of fiber boxes used to ship food has continued to rise. The next most significant markets are containers for the shipment of paper and paper products, and clay and glass products. Both are growing and each currently represents about 10% of the market for fiber boxes.

The industry is in the enviable position of not having any major competitors. Its products have soundly beaten the traditional competition and there is nothing presently to threaten the status of corrugated boxes as the number one shipping container. The Association of American Railroads estimates that around 95% of packaged freight is carried in corrugated or solid fiber boxes, and many of the items still shipped in wooden containers have corrugated pads and innerpacking.

Wirebound crates are used extensively for ice-packed vegetables and poultry. This is an area which corrugated cartons have been slow to penetrate because even the moisture resistant boxes lose strength if kept soaking wet more than a few hours. Wooden crates, however, retain their strength under these conditions and thus have an important advantage.

Shipping containers of foamed plastic molded to fit the article represent a kind of competition. For delicate or expensive items requiring a lot of protection, the initially high cost of the specially molded container may be more than offset by the reduction in labor time to package the item, lower shipping costs as a result of weight reduction, and fewer damage claims. Often one or more of these molded containers are encased in a corrugated box for shipping. In these instances, the foamed container acts as a very high-quality innerpacking. In this area the competition from foamed plastics is expected to be felt most keenly. Folded or die-cut innerpacking of corrugated material is time consuming to make-ready and to put in place. In many cases shippers can avail themselves of the cushioning properties of foamed plastics as well as their weight and labor-saving advantages by using foamed plastic inserts at certain critical points to "suspend" the article inside a corrugated box. There

is some thought that this technique will make it possible to package a larger variety of items in corrugated boxes, and that this expanded market will offset, to a greater or lesser degree, the loss of the market for corrugated as an innerpacking.

The advances in bulk shipping of commodities over the past decade have probably not affected sales of corrugated boxes one way or the other. Products usually shipped in bulk are those which can conveniently be conveyed and stored in bulk. Items such as these were not usually shipped in corrugated boxes, but rather in drums or paper bags. As a rule, bulk shipments are confined to large users. The requirements of small users continue to be shipped in the traditional containers, although corrugated is making some penetration of this market. For example, some granular plastics are packed in corrugated containers, and even some liquids enclosed in plastic bags are packed in corrugated boxes.

Although bulk shipment, as we ordinarily think of it, may not present much of a threat, containerization may cut into the corrugated box market. "Containerization signifies a concept of transportation designed to facilitate the movement of goods from a shipper's door to a receiver's platform, by whatever media the shipper may choose, without the seal of the cargo container being broken or its individual contents handled in any way . . . In this context, a container is everything from a box to a high-cube trailer, with or without wheels attached." What effects will containerization have on the physical distribution of goods? One authority has this to say (Containerization--Special Report; Distribution Age, March 1963): Containerization will (1) force a radical revision of current common carrier tariff structures--probably to a ton-mile basis; (2) eliminate a lot of paper work on shipments involving interchanges between several carriers; (3) eliminate manual handling at points of carrier interchange; greatly reduce shortage and damage claims; simplify and cut the cost of packaging requirements; and lower insurance premiums; and (4) force carriers to move cargo in the largest units their equipment will handle, resulting, ultimately, in lower freight costs. The fears by corrugated box makers that containerization may result in reduced strength requirements for those corrugated containers that are used appear well founded.

As I pointed out earlier, the output of containerboard has been highly correlated with gross national product. With economic growth rates commonly bandied about, it is possible to project an output of around 15 million tons by 1970. This means of anticipating the future has an obvious flaw; it assumes that history will repeat. This is a particularly unwarranted assumption at this stage. Since 1947-49, a substantial proportion of the increase in total demand has come from new uses and new markets. Containerboard didn't have too much competition; in fact, it was capturing markets from competitors. Now, the largest and most obvious new use is in the shipment of ice-packed vegetables and poultry. The capture of this market from wooden containers depends on the development of a box which will maintain its strength under high moisture conditions. Big new markets will depend on entirely different fiberboard products.

Meanwhile, some corrugated tonnage will be lost as a result of less stringent requirements of individual units which are containerized for shipment, and as a result of a shift to foam innerpacking. Unfortunately, we do not now have

very good ideas as to the magnitude of these changes. Expanded total demand for corrugated board will come primarily from the growth in old markets and from the packaging requirements of new products. Thus production is unlikely to grow at as rapid a rate as in the past, and the relationship between GNP and containerboard production will probably tend toward 1 to 1.

What do buyers expect of corrugated containers? Of course, there are hundreds of answers, and they would vary according to kind of product (size, fragility, moisture content, etc.), mode of shipment, warehousing conditions, frequency of handling, and use as an advertising medium. But in general the initial buyer expects the container to provide adequate protection for his product at the lowest possible cost.

The scientifically minded buyer will determine the kind of punishment his packages take. In this way, he will be able to design a carton which will hold up under the shocks of manual handling, rail and truck transport, stacking in damp warehouses or what have you, and at the same time provide good protection for the contents. Thus, he will not be paying for too much protection, nor will he have to deal with an excessive degree of damage. What are some of the important elements? They are: (1) Weight of container, (2) compression strength, (3) resistance to puncture, (4) resistance to moisture and humidity, (5) resistance to scuffing, (6) cushioning ability, (7) appearance and printability, and (8) uniformity of product. Fairly objective tests can be employed to check most of these properties. Various tests are also performed on samples of components.

These tests help board makers in their efforts to maintain uniformity in the quality of their products. Despite these tests, the problem of uniform quality is widespread. This lack of adequate quality control leads to waste and customer dissatisfaction. Evidently an additive or process which would impove product uniformity would be welcomed. Its value would depend on the degree of overdesign to compensate for a lack of uniform quality, or the amount of product damage (and associated costs) attributable to carton deficiencies. Each user will have to figure this out for himself.

"The chief requirements of a fiberboard box in service, which vary with the commodity and the method of shipment, may be summarized as follows: (1) high resistance to the failure at the scored edges that results from the thrust of the box contents, (2) resistance to crushing through compression loads and through other objects striking or falling on the box, (3) resistance to mashing when dropped on a corner, (4) resistance to puncturing by sharp objects, (5) ability to absorb shocks without damage to the box contents, and (6) resistance to diagonal distortion and twisting." (The Manufacture of Fibre Boxes, A. W. Werner, Board Products Pub. Co., Chicago, 1954.) There is, of course, a relationship between many of these requirements. A box made heavy enough to withstand compression loads imposed by today's stacking heights would very likely be resistant to mashing when dropped, and resistant to puncture.

Various investigators have established a relationship between the strength of the components and the strength of finished boxes. K. Q. Kellicutt and E. F. Landt of the US Forest Products Laboratory have formulated a "box strength calculator" which can be used to design containers for specific uses based on

the physical characteristics and strength properties of paperboard sheets used in fabricating the boxboard.

The requirement which has received a great deal of emphasis is resistance to crushing through compression. Kellicutt and Landt developed their design data for corrugated cartons around this one property. Implicit in their publications is the thought that in most cases if a box is designed to withstand the compression loads to which it will be subjected, then it will also have the other properties required. Their calculations were worked out for the 3 most commonly used flute types, which allows the designer to incorporate variations in cushioning ability into his calculations.

The strength of corrugated cartons diminishes with rising moisture content of the board. To compensate, cartons, particularly those which will be stacked in warehouses where humidity levels are high, are "overdesigned." That is, heavier material is used. The effects of moisture on the performance of corrugated cartons have also been studied by Kellicutt and Landt. Their results on the relationship of time and moisture content to compression strength have been incorporated in the Box Strength Calculator. This device is a useful tool for determining the extent of "overdesign," and hence the value of products or processes which would reduce overdesign.

Suppose that the compression strength of the components of corrugated board could be increased by a novel additive or process, so that less fiber is required in manufacture. How much would such an improvement be worth? Since corrugated board loses strength as moisture content rises, it is imperative that additional strength be built into the box if it is to be used in other than ideal conditions. Using the Box Strength Calculator, it is possible to figure for any particular box the weight and value of fiber saved as a result of improving the compression strength of corrugated board at high relative humidity. If linerboard compression strength could be increased by 50% at all levels of relative humidity up to 90%, it is possible to show that the savings in weight would approximate 30%. At a value of $120 per ton, the pulp saved in the examples used in the analysis would be worth about $53. If the improvement were brought about by the addition of 5% of some strengthening agent, the cost of the agent could approach 50 cents per pound. Additional savings would be realized through lower freight costs.

At present resistance to moisture is imparted to corrugated board by coating surfaces with waxes. The waxes are refined paraffin and various microcrystalline waxes blended to form fast wetting, smooth coatings with good adhesion and flexibility along score lines. A representative blend for corrugated boxes costs about 7½ cents per pound. (L. W. Potter, Atlantic Refining Co., Philadelphia, Pa.) Application is commonly at the corrugator by sprayers or rollers and by dipping the box blank in the wax bath. Following immersion, the blank is allowed to drain, either in an oven or in cool air following a brief oven draining period. Wax pick-up is controlled by means of oven temperature and/or drain time. Material costs per ton of boxes for the three processes are as follows: Waxing on corrugator, up to $50; dip and oven dry, $45-$63; and dip and air cool, $59-$137+. A wax pick-up of 30 to 35% is normal for service in high humidity atmospheres. Where the carton is to be used in wet service, a wax pick-up of 50 to 100% based on dry board is required.

Waxes are sometimes blended with plastics to improve their barrier properties, scuff resistance, and adhesion to the board. The plastic most commonly employed is an ethylene-vinyl acetate copolymer.

How do boxes treated with waxes perform? The literature is unclear because of the failure to include "controls" in published experimental results. However, US Forest Products Laboratory data show that most of the waxing treatments added compression strength under both normal and high humidity conditions, and that the treated boxes, like the controls, lost a large percent of their strength at high relative humidity. Data on cost of treated boxes and details of treatments were available in so few instances that meaningful inferences could not be made.

At least two conclusions can be drawn from this work. First, despite the fact that most of the boxes, including the controls, lost about half their compression strength at high humidity and retained only 10 to 20% of their original strength after 24 hours in water, half of the initial improvement in compression strength due to treatment was retained at high humidity. Thus, with but two exceptions, all treated cartons outperformed the control carton, many by significant margins. Second, although the margin of improvement in the instance of water immersion is also marked, it is inadequate.

The data also correlate with the following two observations: (1) Corrugated box makers have been able to capture about 60% of the container market for fresh produce, but 80% of the ice-packed poultry moves in wirebound crates. In other words, the improvement in moisture resistance brought about through application of wax is sufficient to make shipment in corrugated cartons more economical where humidity is a problem, but it is insufficient for service where boxes are subjected to a lot of water as well as humidity. (2) Every major corrugated box company is trying to develop a rigid-when-wet carton. We may therefore expect the development of new processes.

I have discussed the size of the containerboard market and its prospects for further growth. Better compression strength at high relative humidity and while soaking wet is high on the list of improvements demanded by users. I have estimated how much an additive which would improve carton performance at high relative humidity would be worth, and mentioned some of the competition such an additive can expect. We hope that the Northern Laboratory can develop a commercially acceptable cereal derivative which will raise the compression strength of corrugated cartons at high levels of relative humidity, and which can be sold at a low cost. Such a development could result in a new outlet for as much as 100 million bushels of cereal grains. This estimate includes possible use in other paper and paperboard products as well as in corrugated board.

PROGRESS ON CEREAL XANTHATE FOR USE IN PAPER MANUFACTURE

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Previous studies have shown that crosslinked xanthates of starch, wheat flour, and bran have industrial potential as wet- and dry-strength additives for paper and boxboard. Preliminary estimates based on laboratory studies indicate that wheat starch and flour can be converted to crosslinked xanthates, referred to as cereal xanthides, for 2 to 3 cents per pound. These cereal products appear to have greatest potential as wet-strength agents for bag papers and as additives for preservation of stiffness at high humidity in linerboard used in corrugated boxboard.

During the past year the following areas of research on cereal xanthates and xanthides have been emphasized: (1) Fundamental chemical studies of starch xanthates to provide a basis for their practical production and application consistent with their inherent structure and properties; (2) semipilot-plant engineering studies of the continuous production of starch xanthates; (3) development of a continuous method for dissolving xanthates in water; (4) microscopic examination of experimental paper to determine the influence of methods of incorporating xanthides in paper on xanthide distribution and to determine the relationship between xanthide distribution and paper properties; (5) development of improved conditions for preparing xanthided papers on a 10-inch paper machine; (6) determination of the stability of xanthided papers in various environments; and (7) initiation of studies on the production of bran and whole ground wheat xanthates and their use in bag and box papers.

Before progress in these seven areas is discussed, I shall review some background and define a few terms. Although limited studies with ground whole wheat, wheat flour, and bran have given results comparable to those achieved with starch, data I shall give are all derived from starch. Starch was studied in detail because it is much more homogeneous than other cereal raw materials; consequently, starch reaction products are more easily analyzed and characterized. Also, starch is the major constituent in ground whole wheat and wheat flour. Bran contains more than 50% starch and related carbohydrates.

Wheat starch is a mixture of about 25% amylose and 75% amylopectin; both are high polymers derived from the simple sugar glucose (see structures, Fig. 1). Amylose contains hundreds of anhydroglucose units all with hydroxyl groups at the 6 position, joined together like the two units at the top of the figure to give a linear polymer. On the other hand, amylopectin is a bushlike molecule containing hundreds of thousands of anhydroglucose units. The bushlike, or highly branched, structure of amylopectin is achieved by joining numerous and comparatively short amylose-type chains to one another through the 1,6-position as shown in Figure 1. On the average, there is one branch point for about every 25 anhydroglucose units in amylopectin.

The amount of xanthation at the hydroxyl groups in the 2, 3, and 6 positions of starch (indicated by parentheses, Fig. 1) will be discussed later.

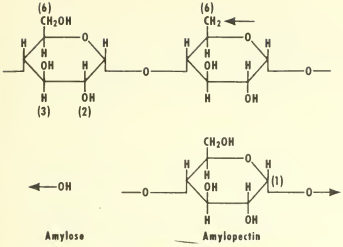

Figure 1. Structural features of amylose and amylopectin components of starch.

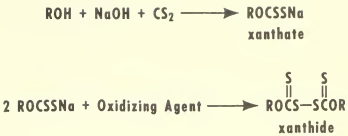

Figure 2. Preparation of xanthates and xanthides.

The term "degree of substitution," usually abbreviated DS refers to the average number of hydroxyl groups per anhydroglucose unit that are xanthated. For example, in starch xanthate of DS 1.0 an average of one hydroxyl group per anhydroglucose unit is xanthated, and in starch xanthate of DS 0.1 an average of only one hydroxyl group in every 10 units is.

Reactions involved in the xanthation of starch and in the oxidative cross-linking of the xanthates are shown in Figure 2. Starch, represented by ROH, is xanthated by treatment with carbon disulfide and aqueous alkali. In less refined materials such as flour, the carbon disulfide reacts in a similar manner with active hydrogens on the proteins. When treated with an oxidizing agent such as sodium hypochlorite, water-soluble xanthate is crosslinked to form the insoluble xanthide. This crosslinking is shown diagrammatically in Figure 3 where the wavy lines represent the starch polymer. Some intramolecular coupling between xanthate groups on the same chain can occur as well as intermolecular cross-linking between chains. During crosslinking the yellow xanthate solution turns

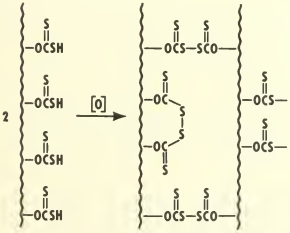

Figure 3. Crosslinking and intramolecular coupling

Figure 4. Yellow solution of cereal xanthate and white precipitate of cereal xanthide.

white as seen in Figure 4. When the crosslinking step is carried out in an aqueous suspension of wood pulp fibers, the insoluble xanthide precipitates on the fibers and is retained to a high degree when paper is made from the furnish by usual processes. The incorporated cereal xanthide imparts high wet tensile strength of a permanent nature to the paper and improves dry-strength properties considerably, except tear.

Fundamental chemical studies. In previous work a small-scale continuous process was developed for the xanthation of starch in a reaction time of 3 to 6 minutes. Since starch had never been xanthated under such conditions before, the xanthates were fractionated to determine whether the starch as a whole was uniformly xanthated, thereby giving the highest possible performance in subsequent applications.

You are all familiar with the term fractionation as it applies to the separation of components of grain in the normal flour milling operation. On a chemical or molecular basis a mixture of molecules differing in molecular size and shape and in degree and type of substitution can be separated by several means. The method employed for the starch xanthates was solvent-nonsolvent precipitation. In such a fractionation starch xanthate was first converted to a more stable form, the diethylacetamide derivative (Figure 5). The resulting

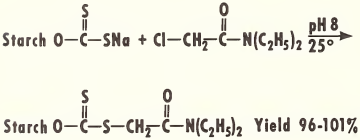

Figure 5. Preparation of N,N-diethylacetamide derivative of starch xanthate.

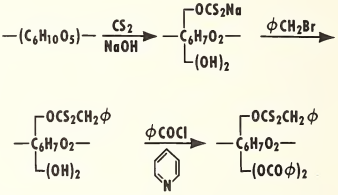

Figure 6. Replacement of xanthate group with methyl group. Part 1.

product was dissolved in dimethylsulfoxide (a high-boiling solvent), and fractions were precipitated from solution by incremental addition of methyl alcohol in which the acetamide derivative is insoluble. The results obtained with starch xanthate of DS 0.12 after aging 1 hour at room temperature following discharge from the continuous reactor are shown in Table 1. All the starting material was recovered, and each fraction had essentially the same nitrogen content and DS. Similar results were obtained with starch xanthate of DS 0.34. Since specially prepared mixtures containing xanthates of different DS were readily separated by this fractionation, it is concluded that starch is uniformly xanthated in our process.

In other fundamental studies, starch xanthates with DS 0.12 and 0.33 after 1 hour aging were subjected to the series of reactions depicted in Figures 6 and 7 to give methyl starches with a methyl group at every position previously occupied by a xanthate group. Each methyl starch was then separated into methyl amylose and methyl amylopectin by complexing with Pentasol. Since

Table 1.--Fractionation of diethylacetamide derivative of starch xanthate, DS 0.12

Fraction	Cumulative weight, %	Nitrogen, %	DS
I	27.6	0.94	0.12
II	46.1	0.93	0.12
III	47.3	0.88	0.12
IV	74.2	0.96	0.13
V	95.0	0.96	0.13
VI	98.3	0.95	0.13
VII	100.0	0.86	0.11
Unfractionated	--	0.93	0.12

each of these two fractions had essentially the same methoxyl content as the parent unfractionated methyl starches, there is further proof for the uniformity of xanthation.

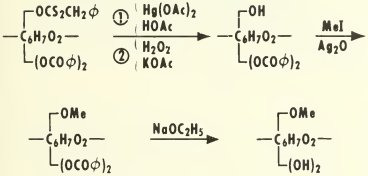

Figure 7. Replacement of xanthate group with methyl group. Part 2.

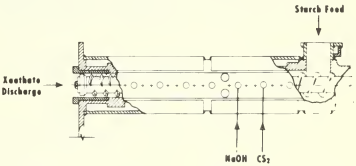

Figure 8. Mixing chamber of 2-inch Ko-Kneader.

The extent of xanthation at the 2-, 3-, and 6-position in the anhydroglucose units of starch was determined as follows: The methyl starches were treated with acid to break all the bonds connecting individual sugar units in the starch polymer. The liberated glucose and methyl glucoses were separated quantitatively by paper chromatography and the fractions identified. Composition of the hydrolyzates from methyl starches of DS 0.32 and 0.13 is given in Table 2. As expected for low DS starches, the

Table 2.--Composition of O-methyl starch hydrolyzates

	DS 0.32		DS 0.13	
Sugar	Mg. found[1/]	Pct. of total recovered	Mg. found[1/]	Pct. of total recovered
D-Glucose	328	66.9	406	88.0
Mono-O-methyl	150	30.6	54.1	11.7
Di-O-methyl	12.2	2.5	1.4	0.3

[1/] DS 0.32, 497 mg. chromatographed; DS 0.13, 470 mg. chromatographed.

amounts of hydrolysis products decreased sharply in the following order: glucose, mono-O-methyl glucose, and di-O-methyl glucose. From the weight yields given in Table 2, the calculated mole ratios of unxanthated, mono-xanthated,

and dixanthated anhydroglucose units in the parent xanthates were 34:4:0.1 for starch xanthate of DS 0.12 and were 32:13:1 for starch xanthate of DS 0.33. The amounts of the 2, 3, and 6 isomers in the monomethyl glucose fractions derived from methyl starches of DS 0.32 and 0.13 were determined by paper chromatography (Table 3). In the fraction from methyl starch of DS 0.32

Table 3.--Composition of mono-O-methyl components

Mono-O-methyl D-glucose	DS 0.32 Mg. found[1/]	DS 0.32 Pct. of total recovered	DS 0.13 Mg. found[1/]	DS 0.13 Pct. of total recovered
2-O-methyl	37.8	27	20.2	44
3-O-methyl	8.4	6	0	0
6-O-methyl	94.0	67	26.0	56

[1/] DS 0.32, 144 mg. chromatographed; DS 0.13, 48 mg. chromatographed.

the amounts of the 2, 3, and 6 isomers are 27, 6, and 64%, respectively. The values for the corresponding isomers in the fraction from the methyl starch of DS 0.13 are 44, 0, and 56%. Distribution of xanthate groups in the original starch xanthates must not have been greatly different from the distribution for corresponding monomethyl glucose isomers (Table 3) because only a relatively small number of anhydroglucose units were dixanthated (Table 2).

In cellulose xanthate, which is used in the production of cellophane and rayon, the relative amounts of substitution at the 2, 3, and 6 positions change considerably with aging. In view of this shift, the distribution of xanthate groups in starch xanthates aged for considerably longer periods than those examined above is being determined because we need to know the rate of change, if measurable, and whether it influences performance. This information will enable us to develop the most effective processing and handling procedures.

Engineering studies on xanthate production. The small-scale continuous xanthation of starch mentioned previously was carried out in a screw-type mixer-extruder called a Ko-Kneader. A cutaway view of the mixing chamber is seen in Figure 8. This chamber is a cylindrical barrel 2 inches inside diameter by 17-1/2 inches long. Three rows of pins or kneading teeth arranged at 120° intervals around the barrel project into its interior. Within the barrel is a 1.95-inch-diameter screw with interrupted flights. In operation this screw reciprocates past the pins on each revolution. This action kneads the material back and forth over the pins to provide intense mixing of material forced through the barrel by the positive pitch of the screw. Starch is metered in at the hopper by a screw feeder, not shown. Carbon disulfide and aqueous sodium hydroxide are pumped into the barrel at the required rate through hollow tubes which project into the barrel at the points indicated in Figure 8. Residence time of starch in the barrel is about 2.5 minutes. The production rate in the 2-inch Ko-Kneader is between 6 and 7 pounds (dry basis) per hour. Starch xanthate being discharged as a viscous reaction product containing about 50% solids is pictured in Figure 9. Analysis of these products within 10 minutes after discharge showed that the reaction efficiency (percent conversion of added carbon disulfide to xanthate) was about 70% for xanthates with DS in the 0.1 to 0.2 range.

Figure 9. Xanthate discharging from 2-inch Ko-Kneader.

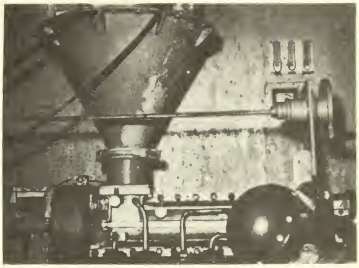

Figure 10. Barrel or mixing chamber of 4-inch Ko-Kneader with vertical starch feeder.

In engineering and development work under our contract at Battelle Memorial Institute, Columbus, Ohio, xanthate production rate has been scaled up to about 200 pounds (dry basis) per hour in a 4-inch Ko-Kneader without difficulty. In addition, a process has been developed for the continuous dissolution of the viscous xanthation product as it is discharged from the Ko-Kneader. Pictures of sections of this larger equipment are shown in Figures 10, 11, and 12. In Figure 10 the barrel of the 4-inch Ko-Kneader with a force feeder for starch on top is shown. The barrel is about 4 feet long and its inside diameter is 4 inches. Starch is metered into the hopper of the force feeder at the constant preset rates by a weigh-belt-type feeder on the deck above.

Figure 11. Xanthate solution discharging from continuous dissolver.

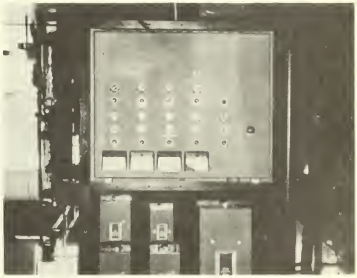

Figure 12. Control panel for 4-inch Ko-Kneader.

Sodium hydroxide solutions and carbon disulfide are pumped into the barrel of the Ko-Kneader as illustrated in Figure 8 for the 2-inch Ko-Kneader. In the middle of Figure 11 a flanged pipe connecting the discharge end of the Ko-Kneader to the intake of the continuous dissolver is clearly seen. Dilution water is forced into the dissolver at a point near the xanthate intake. In the lower center of Figure 11 the xanthate solution flows from the dissolver. In this integrated unit the respective residence times in the Ko-Kneader, connecting pipe, and dissolver are about 2.5 minutes, 5 minutes, and 1 minute. In this system starch xanthate can be produced and dissolved at rates up to 220 pounds (dry basis) per hour. Average reaction efficiency in this system is about 10% higher than that in the small machine. The entire system is enclosed in a ventilated hood and is operated by remote control. One of the control panels is shown in Figure 12.

Microscopic examination of experimental papers. In another phase of the contract at Battelle Memorial Institute, papers selectively stained to reveal xanthide are being studied by both electron and light microscopy. The object is to determine the relation between distribution of crosslinked xanthate in the paper and properties of the finished paper. Eventually we expect to have a procedure which will be useful in correlating application procedures with final paper properties. So far this study has shown that in-situ xanthides (xanthates crosslinked in the presence of pulp) are better distributed than ex-situ xanthides (xanthides preformed and subsequently added to the wood pulp). There was also a positive correlation between good distribution of xanthide in the sheet and strength properties of the paper. For clarification it should be mentioned that the xanthides referred to in other sections of this discussion are all in-situ xanthides.

Machine runs. Numerous runs with starch xanthide-wood pulp furnishes have been made on our 10-inch Fourdrinier machine (Figure 13) to determine preferred application procedures and to provide information that will expedite industrial acceptance of cereal xanthides. At the far left is the headbox

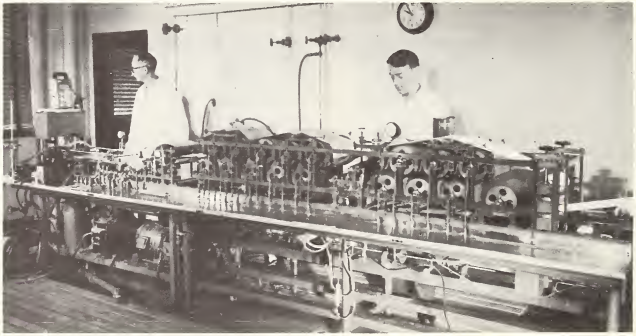

Figure 13. Ten inch fourdrinier paper machine.

which delivers furnish to the wire screen where water is drained off to form a wet mat of fibers. The wet mat of paper as it comes off the wire is picked up by press rolls that further reduce water content. From the press rolls the paper moves through two banks of heated drying rolls (left and right of center, Fig. 13). The paper then passes through a small calender stack or set of smoothing rolls and is finally wound on the windup roll at the far right. As a result of studies with this machine, retention of xanthide at 5 to 10% levels of addition, based on dry pulp weight, has been increased from the previous average of about 60 to nearly 90% by addition of 2% alum and recycling of white water.

The effect of xanthide content on strength properties of an average set of 42-pound linerboards is shown in Figure 14. In machine-made paper, between 4 and 8% of xanthide gave maximum strength increases over the untreated control

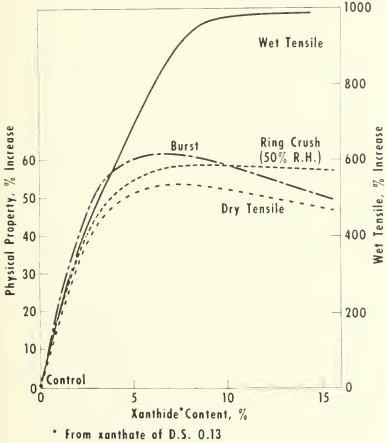

Figure 14. Effect of starch xanthide content on properties on linerboard.

paper. These increases were on the order of 1000, 45, and 60% for wet tensile, dry tensile, and burst, respectively. The maximum increase in ring crush (55%) at 50% RH occurred at a xanthide content of about 6%. This paper after exposure to 90% RH for 72 hours, the usual test period, had a ring crush equal to 65% of the strength of the untreated control at 50% RH. About the same results were obtained with 42-pound linerboard containing 6% phenolic resin. Industry would like to have a treated board which at 90% RH has a ring crush equal to 90% of and untreated board at 50% RH. Although we are short of this goal, we believe it may be reached because recent improvements in the method of incorporating xanthides in paper have indicated that the 1000% increase in wet strength mentioned above can be achieved with half the amount of xanthide formerly required.

Weathering tests. In accelerated weathering tests in a Weather-Ometer where conditions of heat, light, moisture, and time were equivalent to about 4 months outdoor exposure in a temperate zone, 42-pound linerboards containing 4-8% xanthide lost less crush strength percentagewise than the untreated control. Wet tensile strength decreased slightly at the lower xanthide level but remained constant or increased slightly at the higher level. These results indicate that xanthided board and, by inference, xanthided papers have reasonably good stability. On this basis they should meet the requirements for a number of premium-quality paper and board products.

Bran and related raw materials. Studies have been initiated under another contract at Battelle Memorial Institute to determine the suitability of wheat bran and ground whole wheat as raw material in xanthates for use in papermaking. Because these materials are cheaper than starch, they should provide significant savings, but studies have not progressed far enough to determine performance and overall costs.

Summary. A considerable body of fundamental information on the structure and properties of starch xanthates has been developed which has been, and will continue to be, useful in guiding our research. The method for continuous xanthation has been scaled up to provide data for firm cost estimates and materials for use in semicommercial trials. Methods have been developed for determining the effect of application variables on xanthide distribution in paper and in turn relating this to paper properties. Improved conditions for continuous production of xanthided papers on an experimental paper machine have been developed. Reassuring information has been obtained on stability of xanthide papers to adverse conditions. Lastly, studies on bran and ground whole wheat have been initiated to provide even cheaper cereal xanthides than the low-cost products already derived from starch.

Future studies. The following five areas will be emphasized in the future: (1) Determination of performance of cereal xanthides on a larger and much faster paper machine than the one now used. Provision has been made for delivery and installation of a paper machine that will produce paper up to 24 inches wide at speeds up to 500 feet per minute. (2) The development of more active ex-situ xanthides, which unlike in-situ xanthides need not be prepared at the paper mill, thus placing cereal xanthides within easier reach of small mills who may not be able to afford the equipment and personnel required for xanthation and in-situ preparation of xanthides. (3) Continuation of studies on xanthation of bran and ground whole wheat to determine whether these materials will further reduce costs. Development of physical and chemical methods for eliminating bran and whole wheat particles which produce objectionable specks in paper. (4) Development of conditions for preparation and application of cereal xanthides which will further increase their present high performance in paper. (5) Rigorous evaluation of stability and performance of xanthided papers and boards under a wide variety of artificial and natural conditions of exposure.

PRODUCTS FOR THE PAPER INDUSTRY FROM THE PACIFIC NORTHWEST

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In approaching a subject such as the industrial utilization of wheat, the temptation to follow along well-established lines is very great. Wheat is complex, separable into readily identifiable parts by various techniques--some of which are almost as old as western civilization. Investigators are usually men with training in processing. Their thinking usually includes sufficient processing to result in an improved product with properties more uniform and reproducible than the raw materials. Such an approach may be intellectually satisfying, but it ignores a basic economic problem. Whenever any substance is separated into parts, a market must be found for all parts or the product must have a price sufficiently high to permit destruction of unwanted fractions. In the production of starch from wheat, for example, the bran, gluten, and other parts must be disposed of, if possible at a profit.

As a source of starch wheat has long been in competition with corn, barley, rye, milo, potatoes, tapioca, tamarind seed, sweet potatoes and other materials. In this competition, wheat has not won out as a major starch source because of factors which make its use uneconomical. Among these are: (1) lack of an adequate, properly priced market for the high-protein co-product, gluten, (2) lack of an adequate, reasonably-priced market for bran, (3) a higher processing cost than that for some other materials, notably corn and potatoes, and (4) a high raw material price. Since the three common simple products (bran, gluten, starch) are unable to compete in the high-priced food and feed field, it seems unlikely that more elaborate fractionation will produce products sufficiently low-priced to compete with currently entrenched materials in the wood products or paper industry. With this attitude in mind, a cooperative program between the Northern Utilization Research Laboratory of USDA at Peoria, Ill., and Washington State University's Division of Industrial Research was instituted to study and if possible discover new and practical uses for wheat in the wood and paper industry. Most of our work has been concerned with applications in the field of paper and in this we have had the kind and very greatly appreciated cooperation of the Boise-Cascade Corporation at Wallula, Washington. Dwight L. Miller and W. K. Trotter of the Economic Research Service of USDA have also been most helpful.

Most paper is white, bleached, and refined. Large quantities of fine and modified starches are used in the manufacture of such paper as shown in a survey of industrial uses of cereal grain products in the wood products industry (Research Report No. 64/3-71 of our Division of Industrial Research). If wheat is to replace the products currently used in fine papers it will require skilled processing of the types currently being examined by other investigators.

Much paper is relatively crude. Unbleached kraft finds major tonnage use in paper bag stock, corrugating stock, linerboard for boxes, industrial paper, butcher stock, etc. Most of these materials contain significant quantities of starch in some form, and the material used is frequently fine white starch made at a high refining cost. Such starches are frequently shipped from great

distances, while wheat is grown in the immediate vicinity. If a crude material could be produced locally, perhaps even on the farm, it could compete economically, if only by savings in transportation. Since there is always a charge for transport of wheat to the processing plant and a second charge for the returning processed material to place of use, the saving could be substantial. In unbleached stock, it might even be possible to utilize the entire ground wheat berry as an additive.

Thoughts along these lines represent our thinking and we have attempted to discover whether whole wheat berry, processed in the most primitive fashion, might be a good to excellent paper additive. Our early efforts to interest paper mills in these materials on a small scale were not encouraging. Most people contacted felt that it would be impossible to use such materials as wet-end additives because of balling in the header boxes. Paper scientists interviewed felt that dry-end addition, even on heavy unbleached kraft stocks, would reduce tear strength and cause difficulty because of high viscosity of the solutions, and all feared adverse effects of protein in the unseparated wheat flour.

Small-scale tests on hand sheets produced uncertain results. It is certainly true that if wheat flour is treated exactly as if it were wheat (or other) starch in making paper, it will not serve. If however it is used with modification and imagination, it is our belief that it can be used successfully in making kraft linerboard and bag stock and that its price can be kept low enough to compete with materials currently used--at least in our northwest region. Large-scale paper mill trials confirm this idea and this opens a major potential market for northwest white wheat based, not on a subsidy or concession, but on genuine value as the best material available at the most reasonable price.

This has been a difficult year in which to evaluate wheat's position in the industrial grain market. The new wheat bill has produced changes in this area which even skilled economists have refused to try to evaluate. In addition, a redefinition of wheat flour for overseas shipment temporarily reduced the availability of second clears in the Pacific Northwest to the vanishing point. The best available estimate of the cost of second clears in this area on June 1 was $4.75 per hundredweight f.o.b. Spokane. Burr or hammermill ground wheat has been quoted at prices varying from $2.75 to $4.50/cwt. f.o.b. several points in Washington but the price is not firm and contracts have not been written. Rye and barley flours are substantially cheaper but their ability to strengthen unbleached kraft paper appears to be substantially below that of wheat flour. Starches currently are quoted in this area as follows: potato, $5.42/cwt., Wallula; tapioca, $4.74/cwt., Portland; tamarind seed flour, $10.50/cwt., Portland. It is not possible to foresee the relative prices of second clears and whole ground wheat at the moment but it appears that the price of impact-milled whole wheat berry should be at least $1.00/cwt. below the current price for second clears.

Our work in producing whole-grain flour has concerned itself with three types of grinding equipment representing readily available commercial or potentially commercial units. A large sample of commercial material made by grinding with the Anthony burr mill was tested. This will be referred to as extender flour because it is used as an extender for resin glues for plywood.

A second sample was also prepared with a rather primitive farm-type burr mill, and we shall refer to this as burr-mill-ground material. The third large-scale sample was made on a special high-speed impact mill, the Unifine mill, developed some years ago by Washington State University. Details on construction of this unit are contained in Washington State Institute of Technology Bulletin No. 206, April 1950. Whole wheat flour made with this Unifine mill is unusual; it shows excellent long-time keeping qualities, which is not usual with whole wheat flour. The flour produced without sieving is reasonably fine although the bran is not finely subdivided. The extender and burr-mill samples were made from the Gaines variety, which is currently the most popular and high-yielding in our area, while the sample ground in the Unifine mill was made from Brevor, a variety of soft white wheat popular with growers in our area, which has a good light color and a strong waxy starch.

The three samples do not differ greatly in their sieve analyses. All are resistant to sieving and tend to collect on sieves in balls. At least 70% will pass through a 100-mesh screen. Further details on composition can be obtained from Research Report No. 64/3-70, Industrial Utilization of Wheat Flour Products, published by the Division of Industrial Research at Washington State University. Tests were made on the ability to bleach these whole-berry flours with chlorine by conventional processes. There was an observable color improvement, but the amount of bleaching possible was small, undoubtedly because of the bran. The burr-ground and Unifine flours were bleached by the use of Novadel (a commercial bleach whose major ingredient is benzoyl peroxide) and showed some improvement in color but not much. The samples utilized in the full-scale paper-mill tests had been bleached with Novadel, but this procedure is a waste of time and money. The improvement in color is not significant in flour used as a wet-end additive in unbleached kraft linerboard .

Paper mill tests. Roy Wiberg and John Sullivan of Boise Cascade Company brought their experience with paper additives into this test. Their cooperation is gratefully acknowledged, for it is always difficult to find permission to make full-scale tests on a production machine, particularly since the experiment may be very expensive.

The paper machine at Wallula produces a web 150 inches wide at speeds near 1350 feet per minute when operating on 42-pound stock. The feed stock is kraft from mixed species and operation is conventional for a Fourdrinier machine. The dry-end additive is flowed on the paper six rolls ahead of the final calender. The following specifications were desired for the paper being produced at the time the tests were run:

Basis weight- - - - - - - 41-43 pounds per 1000 sq. ft.
Mullen test- - - - - - - -100 minimum, 106 target
Moisture content- - - - - 5.0 - 6.5%
Vanceometer- - - - - - - -30
Cobb- - - - - - - - - - - top 70-100, bottom 70-100

The Mullen test indicates the bursting strength of the paper; the Vanceometer indicates printing quality as measured by its absorption of a standard oil; and the Cobb test measures the absorptivity towards water.

Materials being used as a dry-end coating solution must have a very low viscosity (near that of water) in order to flow on properly. Commercial

procedure indicated use of an 11% solution of potato starch reduced in viscosity to a 20-second Zahn No. 2 value by use of a commercial starch-liquefying enzyme. The viscosity of water at room temperature is 18 seconds Zahn.

Whole-wheat flour is difficult to liquefy to the same degree of thinness as pure starch or materials predominantly starch, because it contains a high percentage of protein which is not thinned by a starch-converting enzyme. There are however enzymes which liquefy proteins, and some react under conditions of pH and temperatures similar to the requirements of starch-converting enzymes. After this double conversion, it should be possible to use wheat flour as a dry-end additive provided the bran does not interfere with coating of the linerboard or cause difficulty in flowing the solution on the paper. A conversion of the burr-milled whole-wheat flour with starch- and protein-liquefying enzymes was successfully made, resulting in a Zahn viscosity at 208° F. of 17 seconds for the final material. This is extremely fluid, certainly sufficient to allow it to flow readily on paper.

When however it was attempted to coat the top of the paper only by conventional dry-end methods, the material did not feed easily into the machine and there was a tendency to pile up at the ends of the feeder despite the low viscosity. This probably is caused by unconverted bran. The addition of starch to the extent of 7.5 pounds per thousand square feet of paper resulted in lowering the Mullen test and presently both the Cobb and Vanceometer tests could not be met. This test produced two rolls of unsalable linerboard weighing 22 tons, and this large figure illustrates why such tests are not run frequently. This occurred despite the fact that every effort was made to make the run as brief as possible. The failure does not prove that burr-mill-ground wheat flour is an unsuitable dry-end additive. It does prove that it is unsuitable as an additive when converted by the temperature schedule used, the enzyme concentration selected, and with the bran that was present. With greater care in the conversion than was exercised during our first test and with possibly some modification of the device which feeds the solution on the paper, it may be possible to utilize wheat flour as a dry-end additive, but this remains questionable. It came as a surprise to us to observe, however, that bran particles on the surface of the paper are apparently not significant. Plans had been made to test the other types of flour available as dry-end additives, but neither management nor operators were favorably disposed to further experiments.

Prior tests on hand sheet had been made by mill personnel at Wallula using second clears, barley flours, 150-mesh impact-milled wheat, 200-mesh impact-milled wheat, potato starch, and tamarind flour at several concentrations with and without a retention aid. These tests indicated that second clears and 150-mesh impact-milled wheat offered promise as Mullen increasers, particularly when the retention aid was added. Barley flour and potato starch were not as satisfactory. Some preliminary work with rye flour at Pullman indicates it is substantially inferior to wheat as a wet-end additive, but the tests are not conclusive. The prognosis for a wheat-flour wet-end test was therefore good and management consented to let us continue. Prior small-scale tests at the factory had indicated that extender flour was a satisfactory additive, provided it was added at the rate of around 5 pounds per 1,000 square feet and that Nalco 632 (a polyacrylamide) was added as a retention aid.

It is difficult to hold a cooked wheat flour as a concentrated water suspension or to precook and then add it. This difficulty was surmounted by forming the wheat flour into a fairly concentrated water suspension and then diluting it and cooking it during travel from the storage tank to the stuff chest by injecting steam into it. This jet cooking avoids all difficulties with storing and diluting jelled starch and also completely eliminates any difficulties with balling in the header box. During the run in which the material was added as a wet-end additive, a suspension of approximately one pound of whole wheat flour per gallon of water was made up in cold water and one pound of Nalco 632 per 5 pounds of starch was added. This solution was removed continuously from the tank at the rate of 3 gallons per minute, diluted to 20 gallons, heated continuously to 220° F. by the injection of live steam into the pipe, and sent to the output of the last decker ahead of the paper machine.

The decision to feed this material into the decker outlet rather than the fan pump resulted from the fact that no filter was available on the outlet from the jet cooker tank. By feeding farther back, less likelihood of trouble existed and feed of the additives should be identical to the top and bottom sheet after a short period of adjustment. Utilizing this procedure and using wheat flour at approximately 5 pounds per 1,000 square feet of paper, no difficulties were encountered in meeting any of the standard tests and it was possible to increase the speed of the machine by approximately 6%. During the wet-end tests, which extended over a considerable period, not the slightest trouble was encountered. Mullen tests went up so sharply with Unifine flour that it was possible to increase the machine speed. There is no tendency of the wheat flour to lump; it disperses readily and can be handled simply at a high solids content. There is no increase in steam usage on the machine and the flat box vacuum is unaffected. Savings of around $20,000 per year over competing substances could be obtained by changing to this material now if available at $4.00 per/cwt. This saving accrues from the ability to increase the Mullen and to permit higher machine operating speeds. During the preparation of the concentrated wheat slurry ahead of the jet cooker, the wheat flour formed a very persistent foam in the dispersing tank, and it was feared that it might cause foaming troubles in the white water basin, but this did not occur. Ordinary antifoam agents had very little affect on the stable foam when added to the first tank. The antifoaming agent regularly added to the paper stuff chest seems adequate to cope with the flour foam problem.

In conclusion, it appears certain that unrefined impact-milled wheat flour is a superior additive for unbleached boards and heavy paper. As a wet-end additive at around 5 pounds per 1,000 square feet of paper, such flours increase bursting strength at a lower cost than competing materials. As dry-end additives, wheat flours may yet prove to be desirable, but more work must be done on the double enzyme conversion and the effect of bran in the header box.

Currently we know almost nothing concerning what constitutes the proper grind for a paper additive. Certainly for a wet-end addition it is essential that the material be fairly fine, enough to be free-flowing through 80-mesh screens. For a possible dry-end additive we simply do not know.

The effect of wheat variety on suitability for wet-end addition has not been investigated. Our runs tend to indicate that Brevor is superior to Gaines, but these indications are not conclusive until both have been tried at optimum methods of grinding. A search through currently popular Northwest varieties might well produce a superior additive. During the next year we hope to learn a great deal concerning the effects of grinding on at least one variety and in cooperation with the Washington State Wheat Commission we are producing an experimental Unifine mill which we feel will be most useful in this work. We have applied to the USDA at Peoria for a small grant to enable us to continue our study on variety and on possible bleaching effects with unseparated whole-wheat flours. With the experience gained by our work with unbleached kraft, we want to extend these studies to fields involving higher quality paper. We know that a good job of separating the bran can be done with a simple air separator and that some bleaching is possible. The use of wheat in the paper field has been most limited and much of the material which it may be able to replace is of foreign origin. A continuing study of how to introduce wheat into this industry might well provide a large new market. We believe that sometime during 1964 or early 1965 we will find at least one mill totally converted to the use of whole-wheat flour. If this is as successful as we expect it to be, the use of whole-berry impact-milled wheat flour may well become substantial, solely on the basis of its merits.

NUTRITION RESEARCH -- NEW HOPE FOR WHEAT

H. H. Lampman
Wheat Flour Institute, Chicago, Illinois

Are you easily frightened? If I should say to you--with a note of alarm--"Look out, there's a man behind you with a knife," what would you do? Your own instinct would prompt you to immediate and defensive action. In the same way, you have good sense to drive slowly in fog and rain--even though the posted speed limit may be 65 or 70 miles an hour. Or, no one needs tell you to flee a burning building.

But does your instinct for self-preservation extend into the realm of ideas? Ideas have power, force, vigor, drive. They can destroy; they can create and build. Ideas served as a cornerstone in the foundation of our own Nation. Ideas fomented the French revolution...the Russian revolution. Ideas strong enough to move men to action make our country what it is today--with agriculture, industry, commerce and government all serving the best interests of the people. Now, what does all this have to do with our meeting here today?

My assigned subject, "Nutrition Research--New Hope for Wheat," represents the expression of ideas, ideas which can build or destroy. There are perhaps dozens of scientists in this room better equipped to speak on such a subject than I am--a man sometimes described by people with advanced degrees (affectionately I hope) as a "lay person." Just look at your program, the speakers and subjects. But perhaps my lack of scientific qualification is the real reason I was chosen to speak--because I can speak without restraint. Or, as some would put it, "Fools rush in where angels fear to tread." Because I am

neither a nutritionist nor a research worker, I speak freely. Perhaps a better title for my talk would be "What you don't know will hurt you."

What does it take to appeal to the instinct for self-preservation among wheat growers, millers, bakers and others associated with wheat--to move them to action? How can ideas best be expressed to provoke thought and action among you as individuals as well as representatives of the several industries or agencies involved in the complex of wheat from farm to table? In a speech last January before the National Association of Wheat Growers, the Chairman of our session this afternoon, Mr. Cap Mast, President of the Millers' National Federation, declared: "We have no future without research. For wheat growers, millers, bakers and others associated with the cereal industries--it is research or perish." Amen.

By research, I don't mean questions of economics, wheat prices, foreign markets, grain grades, millfeeds, gluten exptraction, or paper sizing. Those subjects represent problems of grave concern and they deserve your serious consideration. But they and all the other subjects under discussion here thus far are secondary and seem to me unimportant unless we give thought to wheat as food for man.

In these days scientists can make "meatless meat" and "wheatless bread." There are those who believe that one day such foods will be commercially produced, distributed, and served, to meet the nutritional requirements of exploding world population. In that light, you have no choice but to consider the impact of research--human nutrition research--on your personal life, your family income, your industry. You have no choice but to weigh the impact of research on the nutrition of the Nation and the world. Otherwise, none of us would be here. Let us repeat--what we don't know can and will hurt us.

What we don't know about the nutritional contribution of wheat has already hurt us. When Dr. George W. Irving, Jr., Deputy Administrator for Nutrition, Consumer and Industrial Research, Agricultural Research Service, appeared before a Congressional Committee this spring, he said: "Wheat and wheat food products are important in the diet, and yet we know far less about wheat and its nutritive value than we should know...We do not have complete, precise information. Both the analyses and nutritional studies (of wheat and wheat products) are essential to meet some objections that are being raised here and abroad to the incorporation of some wheat products in human diet..."

In other words, ladies and gentlemen, it's later than we think. Questions about the use and value of wheat products have already become a deterrent to their acceptance and consumption. Those questions are roadblocks in your marketing plans--both here and abroad. The virtues of wheat, one of the oldest foods in the service of mankind, are no longer taken for granted. Its benefits are being questioned. According to the US Department of Agriculture, the only reasons wheat products are included among the four groups recommended as a guide to food selection for good nutrition are: (1) wheat products are plentiful; (2) wheat products contain nutrients needed in popular diet, chiefly as the additives of enrichment--thiamine, niacin, riboflavin, and iron.

If that be our only claim to consideration, we certainly haven't much to offer. Grass, leaves, the algae of the sea, or any one of a dozen or more products of nature or agriculture are certainly plentiful. And you can add commercially produced nutrients, vitamins and minerals to anything, or take them by themselves as pills or capsules.

I hope by this time I have taken some skin off the hide of our complacency and rubbed enough salt in the wound to move you, and the various segments of the industries and groups you represent, to action. Before one acts intelligently--expecially when you start to tinker with ideas that so often possess explosive force--you need a plan. To escape from a burning building makes good sense. But to ride off in all directions at one and the same time is not only ludicrous but wasteful and in vain.

Today, it is my happy lot to offer a program of needed research on the contribution of wheat foods in human nutrition. It is a plan devised by people who believe that "the future of the cereal industries--which includes the future of wheat producers, processors, and those who make and sell final products--increasingly depends on demonstrating the nutritional potential of cereal foods and increasing their acceptance in human diet."

Some of the architects of this master plan are here today--talented, highly trained, experienced and competent people. They believe that the position of wheat as the staff of life from the beginning of time is well deserved. That pro tem committee for human nutrition research includes: Dr. C. E. Barthel, Jr., Executive Director, the Research Foundation of Kansas; Dr. William B. Bradley, President, American Institute of Baking; Mr. W. W. Graber, who represented Bulgur Associates, Inc.; Mr. Robert Green, Director, National Macaroni Institute; Dr. D. Mark Hegsted, Professor, Department of Nutrition, Harvard University; Mr. Robert Huffman of the North Dakota Wheat Commission; Dr. Ruth M. Leverton, Assistant Administrator, Agricultural Research Service, US Department of Agriculture; Mr. Howard Morton, Director, Committee on Utilization, Great Plains Wheat, Inc., and the general chairman of this meeting; Dr. James W. Pence, Chief, Cereals Laboratory, Western Regional Research Laboratory, USDA; Dr. Fredus N. Peters, Jr., formerly chairman of the Cereals Committee, Food and Nutrition Board, National Research Council, National Academy of Sciences; Dr. J. Richard Stockton, Director of Research, The Pillsbury Company; Dr. Betty J. Sullivan, Vice President, Research, Peavey Company Flour Mills; Dr. LeRoy Voris, Executive Secretary, Food and Nutrition Board; and Mr. Harold West, Administrator, Idaho Wheat Commission.

It took more than three years, a dozen or so meetings, much correspondence and 10 drafts of the basic document before this group reached final agreement on a master plan of needed research. Let me summarize (a difficult task) some of the points made in that program:

"The ever-growing concern about adequate and proper food for the increasing populations throughout the world in the years ahead cannot be lightly dismissed. The rapid and extensive advances in agriculture and pertinent areas of science and technology have provided mankind with new and approved food products, but the cold fact is that the amount of arable land per individual available for producing food is rapidly decreasing over the world. According

to present population trends, by the year 2000 arable land in the United States will be less than 1.2 acres per person. At the same time, in other parts of the world less than half an acre of land will be available for producing the needs of each person.

"Wheat is a major world commodity. Of the more than 70% of the world's croplands devoted to the production of grain, 22% is used for wheat, the largest land area used for any crop.

"Increases in the yields of wheat per acre have been striking during recent years, from a national average of 12 bushels per acre a few years ago to over 25 per acre in the early 1960's. Yields of as much as 150 bushels per acre have been realized for some varieties under experimental conditions.

"It is important that arable land planted in wheat will provide more nourishment for more people than the same land used for non-cereal food, like meat, milk or poultry. For example, 7 to 8 pounds of grain are required to produce one pound of meat.

"Wheat foods are rich in carbohydrates, protein, and certain vitamins and minerals. Protein adequate in quality and quantity can be furnished in diets containing cereals in large amounts and protein from animal and other sources in small amounts. Further, they may be distinct advantages to such high-cereal diet. It is known that heart diseases and associated afflictions are less frequent in those areas of the world where wheat, rice and other cereal grains are consumed in greater quantity.

"Despite worldwide and domestic needs for foods that contribute to a balanced diet and good nutrition, and despite the extensive production of wheat, knowledge of the nutritional contributions of wheaten products in human diet is relatively scant. We know very little about what is perhaps the first and oldest of all foods, the basis of diet for civilized man in the Western hemisphere. The value of wheat and its products is frequently underestimated.

"The prestige and popular acceptance of a commodity like wheat or flour is essential to the continuation of its marketing success. On this basis alone, studies demonstrating the nutritional value of the product are an important and legitimate part of the American agricultural program--of equal and humanitarian benefit both domestically and overseas.

"Wheat demands a cash market, the foundation of the producers' economy. And while the domestic market continues to be sustained by population growth, per capita consumption of wheat products in general continues to decline. There are suggestions in present research that make the future of wheat as bright and promising as any food produced in American agriculture--if only we had the answers."

In 40 following pages, the text of the master plan sets forth the urgent need and suggests the incalculable benefits to mankind in such a program of research. The document will be published, and--it is hoped by those who joined in its writing--given national and international circulation. But the best laid plans...

Even in published form, the master plan is nothing more nor less than the blueprint of a dream. By their nature, dreams are nebulous. The same group that joined in drafting the outline of needed research is now engaged in the second step--to make the dream take shape as reality in an ever-growing body of knowledge concerning the nutritive values of wheat products. In its final paragraph, the outline states:

"All those associated with wheat and its economy--from the time it is planted, through harvesting, trading, transportation, milling, baking and its production into other food products--government, industry and agriculture--shall all share equally in the responsibility for the diligent and effective prosecution of individual projects described as lacking...To shirk any part of this personal and group responsibility is to shrug off our obligation as producers of food for man and to evade recognition of present and future need."

When the document is published and circulated early next year, we would welcome your contributions--in thought, time, energy...and, if need be, money. Like attorneys, research workers can't think or do without money. So on D-Day, H-Hour, I hope we all stand together.

NUTRITIONAL RESEARCH ON WHEAT IN THE AGRICULTURAL RESEARCH SERVICE, USDA

Ruth M. Leverton
Agricultural Research Service, USDA, Washington, D. C.

The US Department of Agriculture has national responsibility for the production of enough food and a proper assortment to meet the nutritional needs of the Nation within the general framework of food habits and standards. Agriculture must be the highest authority on the inherent values of its products that make them useful and attractive to consumers, and must be in a most knowledgeable position to advise consumers on selection of food assortments that redound to their benefit. To assist in this broad responsibility, the Department conducts research in nutrition and the effective household use of food. Included are studies of human metabolism and requirements for nutrients and food; the nutrient composition, biological value, and consumer-use qualities of food; food economics; nutritional appraisal of diets and food supplies; and periodic surveys of food consumption and nutritional state of people. The research is consumer oriented, multidisciplinary, cross-commodity, and characterized by the overview of food as a dynamic force throughout the lifetime of every consumer.

This report will be limited to examples of our food and nutrition research that involve wheat. Some of the findings have been extracted from studies which include all food commodities. Others come from studies designed to focus directly on the value of wheat in human nutrition.

From periodic estimates of the national food supply, we routinely provide considerable information about the use of the food commodities and their contribution to the nutritional value of diets in the USA. Figure 1 shows the changes in the sources of food energy (Calories) and in the total food energy

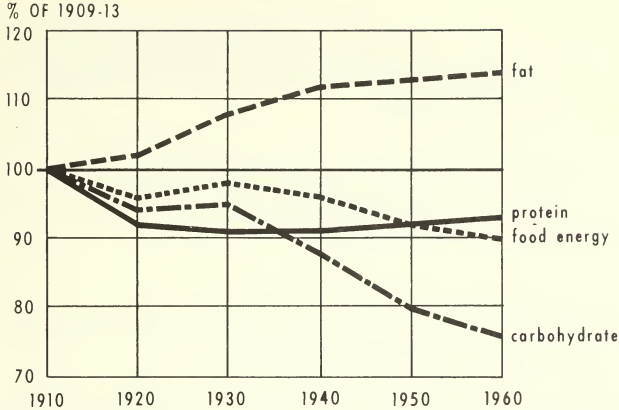

Figure 1. Food energy and sources--per capita civilian consumption.

available per capita since the 1909-13 period. Total food energy is now only 90% of the 1909-13 level, and protein 94%. Greater changes, however, have occurred in the fat and carbohydrate. Fats have risen to 116% and carbohydrates have dropped to 76% of their respective levels in 1909-13.

More detailed study shows that the source as well as the amount of the energy value from carbohydrates in our food supply has changed over these years. Figure 2 illustrates the changes since 1910. Then flour and cereals constituted 57% of the carbohydrate supplied and sugars and sirups 21%. By 1935 these percentages had changed to 44 from flour and cereals and 30 from sugars and sirups. Today the figures are almost equal--37% from flours and cereals and 35% from sugars and sirups.

The possible relation of such changes in source of carbohydrate to circulatory and heart disease and to normal fat metabolism has been noted frequently. In studies with rats, our nutrition scientists have reported that type of carbohydrate had a greater influence than type of fat on the proportion of the food intake stored as body fat. Rats given sucrose as a source of carbohydrate stored a higher percentage of their food intake as body fat than rats given their carbohyrate in the more complex form of starch, in this case cornstarch. Sucrose as the sole source of carbohydrate also caused rats to accumulate excess fat and cholesterol in the liver, the kidneys to become enlarged and damaged, blood cholesterol to be increased, and life span to be shortened. Such findings remain to be validated for application to human nutrition but provide important leads for needed research on the role of carbohydrates.

The question of the possible effect of carbohydrate was raised in our study of the self-chosen diets of professional and business men between the ages of 45 and 55 years, a study made in cooperation with the University of Minnesota.

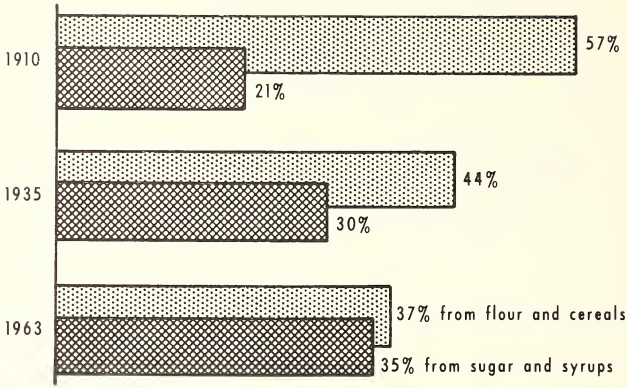

Figure 2. Sources of carbohydrate in US food supply.

There were only slight differences in the food or nutrient intakes of the men with the highest and the lowest serum cholesterol values. The greatest dietary difference was that the group with high cholesterol values had more calories (about 20% more) from rapidly absorbed simple sugars and from alcohol, and had fewer calories from carbohydrates of grain products, vegetables, and dry beans and peas than men with lower blood cholesterol values. The differences are shown in Figure 3. The men with the lower cholesterol values averaged 696 Calories daily from grain products compared with 616 Calories for men with high cholesterol values. Alcohol supplied an average of 89 Calories per day for the group with low cholesterol values, and 160 Calories for the group with high values.

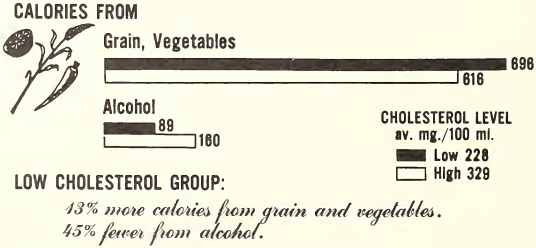

Figure 3. Diets compared for men with low and high blood serum cholesterol.

In our surveys of food consumption we secure quantitative data on kinds, amounts, nutritive value, and costs of food consumed by population groups and practices of families in the purchase and household use of foods. Such data are essential for programs of consumer education and for evaluating agricultural policy and programs.

Our last nationwide survey was made in 1955. One of the publications summarized data collected on frequency of home baking of bread, rolls, gingerbread, quick breads, cake, pie crust, cookies, biscuits, and use of prepared flour mixes. Three out of four housekeeping households in the USA did some home baking during the week of the survey. Fifty-three percent made quick breads and 52% made cake or pie. We are now preparing for the 1965 study which will be more extensive. The study of households will cover seasons and in one season the food intake of several thousand individuals will be recorded.

Our work with the Food Stamp Program has elicited some specific information. The Program is a dual-purpose effort to expand utilization of our abundant resources and to improve the nutrition of needy families. Under the Program, food-purchasing power is increased by giving needy families an opportunity to exchange the amount of money they would normally spend for food for an allotment of coupons of higher monetary value. These coupons are used for the purchase of domestic foods from retail stores at prevailing prices. Retailers then exchange the coupons for cash at banks.

To determine the effect of the Food Stamp Program upon purchasing practices and consumption by low-income families, and the adequacy of their diets, household food consumption surveys have been conducted in several areas before and after initiation of the Program. Special analysis of changes in household food consumption in one large urban area showed that on a per capita basis participating families increased their direct consumption of grains or grain products from 4.8 to 5.2 pounds per week. The indirect use of grains through consumption of animal products increased from 39.1 to 48.4 pounds per person per week, an increase of 24%.

In our Beltsville laboratories, part of our program centers on analyses of foods, including wheat and wheat products, by chemical and physical means to indicate their potential nutritive value. Analysis of market-available foods continues to keep data on nutrient content current with adoption of new varieties and production, processing, and marketing practices. Food properties are altered by heating, chilling, freezing, aeration, physical manipulation, storage, and other practices which comprise household processes of food handling. Therefore we must continue our studies of the quality characteristics of flour and cereals and the relationships between their composition and structure and qualities important to consumers. Such data are fundamental to developing household and institutional methods of preparation which permit optimal use of wheat products.

Another phase of our research is the compilation, evaluation, and publication of data on composition and nutritive value of food. The revised Agriculture Handbook 8, "Composition of Foods," which came off the press just a few months ago, has been greatly expanded over the 1950 edition. The 2,500 food items for which values are given include 200 food mixtures containing wheat

flour, in addition to values for 31 breads, 36 wheat cereal products, 24 alimentary pastes, 10 flour items, and 5 types of wheat.

There is urgent need to determine the biological value of individual foods and of combinations of foods to meet the requirements of the body for energy and the half a hundred substances known to be nutritionally important. Two examples of USDA studies focused on wheat and now underway are given here.

One of the studies is conducted under contract with Dr. Olaf Mickelsen at the Michigan State University. Preliminary findings were reported in September at the Canadian-USA Conference on Nutrition. The purpose was to evaluate the ability of wheat flour to supply the protein needs of young adults. The work of Widdowson and McCance with children in German orphanages following World War II is well known. Only about 10 grams of the total daily protein (51-73 grams) in the diets was from animal sources. The remainder was supplied by bread and cereal and the children grew at normal rates. Little quantitative information, however, is available from work with human subjects on the value of a diet in which all of the protein was supplied by wheat.

In the study conducted at Michigan State, 12 healthy men, college students between the ages of 19 and 27 years, were studied for 71 consecutive days. For the first 21 days they were given a controlled diet adequate in all known essentials and made up of the usual variety of foods. During the succeeding 50 days, 95% of the protein in the diet (67 grams per day) was supplied by wheat flour, the other 5% by fruits and vegetables. None of the protein in this experimental diet was supplied by foods of animal origin. The wheat flour was served as bread and rolls baked fresh daily from commercial all purpose flour, vegetable shortening, sugar, salt, yeast, and water. This diet was supplemented as needed with food sources of fat and sugar to provide adequate energy value in order that the men would neither lose nor gain weight.

Measurements were made continuously of nitrogen balance of each man, and, periodically of his blood values, including lipids and amino acids, the specific gravity of his body, and his pulse rate during the following exercise. There has not been time to analyze all of the data. Results to date, however, indicate that as a group the men remained in good health, and their blood values remained normal. They increased the protein content of their tissues as indicated by nitrogen storage and increased specific gravity of their tissues.

Figure 4 shows the average nitrogen balance of each man for each ten days on the high-wheat diet. During the first ten days as the men were adjusting to the high-wheat diet, the balances were negative, indicating that the men were losing some nitrogen from their tissues. Following this adjustment, however, there was a significant shift to positive balance and storage of nitrogen. The results were not unexpected. The amount of flour which was consumed daily (about 520 grams per man per day) supplied an ample quantity of the essential amino acid lysine. Lysine is often referred to as the limiting factor in wheat because it is present in smaller amounts than the other essential amino acids. Lysine is not a limiting factor, however, when wheat is consumed in quantities that supply the needed lysine.

The last example of our research focused on wheat is part of our Public Law 480 research program. It has been made possible by the cooperation of the

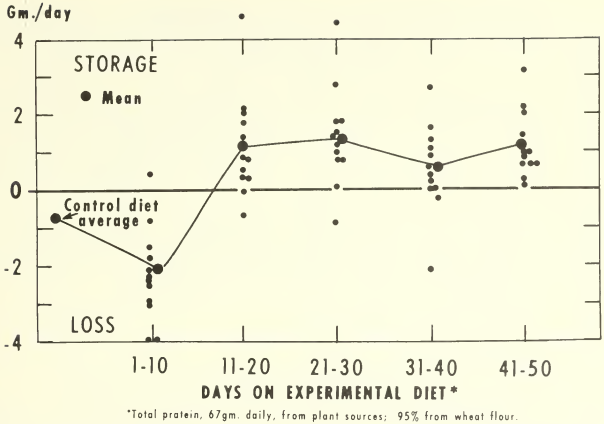

Figure 4. Nitrogen balances of 12 men - -Michigan study.

Foreign Agricultural Service in the Department, the Wheat Associates program in the Far East, and the University of Hong Kong. We are all aware that malnutrition among children is the most serious food and health problem in the developing countries today. There is urgent need for research-based information on practical and economical means of increasing the food and nutrient intakes of children and developing acceptance of foods that are most likely to be available in generous supply in the years ahead. Since production of rice does not keep pace with the needs of the growing population of the rice-eating countries for energy and a staple food, there is both need and opportunity to find dietary supplements and extenders for the rice-eating population. Wheat is one suitable product for use as a dietary supplement and extender. In addition to its abundance and availability, wheat products such as bulgur and enriched flour would contribute important B-vitamins, iron, and protein to the dietary intake. A study was undertaken, therefore, to secure information on the value of wheat as an extender for rice diets commonly used in developing countries, particularly Asia.

The specific purpose of the project was to study the effect on growth and other nutritional indices of children when a significant portion, about 50%, of the rice in their diet was replaced with wheat. In order to secure the most definitive data and locate possible limiting dietary factors, it was advisable to increase the intake of selected nutrients of some of the children by adding supplements.

The general plan of the dietary treatments is given in Figure 5. Approximately 350 children between the ages of 7 and 16 years have been studied at the Children's Garden, an orphanage of over 800 children just outside of

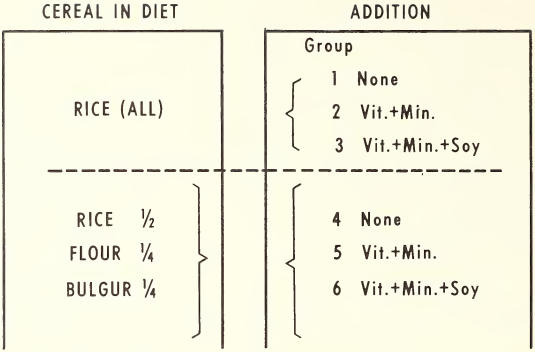

Figure 5. Hong Kong study--360 children, aged 7-16 years.

Kowloon and under the auspices of the Christian Children's Fund, Inc. At the beginning of the study in mid-October 1963, 6 months later, and 12 months later at the end of the study, each child was examined for nutritional status, including selected anthropometric and biochemical measurements. It is of course too early to have final results. Observation, however, coupled with results of the examinations made at the end of the first 6 months, suggests that all of the children were maintained in good health.

A few comments about the acceptability of the wheat--half of which was supplied as noodles and half as bulgur. The noodles were made for the study from enriched white flour and water under the auspices of the Church World Service. They were completely acceptable. The acceptance of bulgur was far from complete or enthusiastic. The greatest barrier was its coarse texture, but its nonwhite color was a serious handicap also. Flavor did not seem to be a major problem. The bulgur could have been more acceptable if it had been ground into a finer farina-type product, even if it still had a light brown color. Older children were more resistant to bulgur than younger children. The development of lye-peeled bulgur at the Western Utilization Laboratory seems promising because of its finer texture and lighter color.

There is definite need in that part of the world for a greater quantity of a cereal staple in the diet. If rice cannot be available in the quantities needed, then wheat in an acceptable form will be used. The orphanages need to use wheat as much as possible because no rice is being distributed free. Any rice used must be purchased. Often a large portion of the budget is spent to buy rice. When wheat products, which are distributed free, are acceptable and can be used, the budget can be spent to secure a more varied, adequate diet.

Now a word about future plans: As many of you know, we received an increase in funds for fiscal year 1965 for research in food science. The full amount of the increase, $250,000, is being spent for research on wheat. We

are using half of this amount to expand our analyses of wheat to measure particularly the trace minerals, B vitamins, and carbohydrate fractions so that we will have authoritative figures for these values. With the other half, we will study wheat in human diets to obtain factual information on its digestibility and utilization as a food. Both the analyses and the nutritional studies are essential to meet some objections that are being raised here and abroad to the incorporation of some wheat products in human diets. With our base funds, we will continue our analytical program on wheat for such other constituents as fatty acids, tocopherols, and amino acids, and study its biological value in rats and micro-organisms.

I trust this discussion gives evidence that we consider wheat and wheat food products important in the diet and that as yet we do not have enough complete, precise information about them. We are convinced that we must know more about their characteristics and their values.

THE EFFECT OF SOURCE OF CARBOHYDRATE UPON LIPID METABOLISM OF MAN

Robert E. Hodges
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There can be little doubt that people in the United States and other highly developed countries are now suffering from an alarming incidence of coronary heart disease which correlates very well with high concentrations of cholesterol and triglycerides in their blood. For some time investigators have believed that this high concentration of fatty substances in the blood and the high incidence of coronary disease were directly attributable to the large quantities of saturated (hard) fats in the diet. It has been disappointing in a number of instances to find that dietary surveys of groups of individuals have repeatedly failed to show differences between people who have coronary heart disease and those who are apparently free from it. On a national level, however, there is a wide difference between amount of saturated fat in the diet and incidence of coronary disease.

John Yudkin, of the University of London, has reported a series of statistical studies beginning in 1957 and continuing to the present. He has shown a rather close relationship between amount of sugar eaten and incidence of coronary heart disease. Further he has shown a striking correlation between increase in fat and increase of sugar in the diet by nations as their economy improves. Thus, a prosperous country will have a high intake of both, and at the same time a decrease in amount of cereals and grains eaten. Yudkin went on to report that people who have evidence of vascular disease either in the heart or extremities are in the habit of putting much larger quantities of sugar in their tea or coffee than a similar group who are free from vascular disease. Also, people who had vascular disease had a much higher total intake of sugar than did a control group.

Our own studies, published earlier this year, indicate that in the United States similar trends have occurred since 1909. For example, we have had a progressive increase in fat and sugar in our diet, but the ratio of polyunsaturated to saturated fats has actually risen instead of falling as one might

have predicted if fats were the chief determinate of coronary heart disease. We find, also, that the use of grains and cereals has declined sharply in the United States and that the intake of readily absorbable carbohydrates such as sugar has increased more than any other factor.

Numerous studies performed in animals have indicated that feeding starch instead of sugar to rats results in lesser amounts of cholesterol in their blood or liver. Several studies in man have suggested that the same thing occurs. Thus, MacDonald in England, Ringsdorf and Cheraskin in the United States, and Pleshkov in Russia have reported that people fed sugar have higher amounts of fat in their blood than they do when they are fed starches. This agrees with reports of Cohen in Israel, who noted that immigrants to Israel from Yemen increased chiefly the amount of sugar in their diet and developed a much higher incidence of coronary heart disease than they had in their native land. In a recent survey, Keys and his group reported that men who had high levels of cholesterol in their blood had a decrease in their consumption of grain products accompanied by an increase in the amount of vitamin C and linoleic acid in their diet, as compared with similar groups of men who had average or low concentrations of cholesterol in their blood.

Our own studies, which have been aimed at evaluating the effects of varying the source of carbohydrate upon fat metabolism, indicate that as starches are fed in the diet the concentration of fats in the blood decreases and as these starches are replaced by sugar the concentration of fats rises.

Undoubtedly there are numerous factors which influence the amount of cholesterol and other fats in the blood of man. The diet is one factor which can readily be modified, and here again, there are several dietary factors which are important. The best available evidence now indicates that the source of carbohydrate is one important dietary consideration which influences the metabolism of fat and may have an important bearing upon the incidence and severity of atherosclerosis.

(The speaker wishes to acknowledge the assistance and sponsorship of the Cereal Institute, Inc., in the investigations reported. Details will be published in scientific journals.)

A REVIEW OF PL480 UTILIZATION RESEARCH PROJECTS ON WHEAT

Robert L. Olson
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PL480 research projects are paid for in foreign lands with soft currencies we get from export sale of farm surpluses. The Western Utilization Research and Development Division sponsors 15 projects in 7 countries on wheat utilization research. Money values and cost of research vary from country to country so that equivalent dollar costs don't provide a good estimate of the program's size. We estimate that PL480 funds support a program with about a third the number of scientists of the program in the Western Division. However, many of the projects will terminate in the next two years and the program will be reduced. I

will review this program and report progress briefly. First, however, I will provide a framework by summarizing the wheat program in the Western Division in Albany, Calif.

The basic aim there is to expand markets to the full capacity of US agriculture. The emphasis is on (1) developing new products to increase overseas dollar markets and build long-term markets in developing nations; (2) increasing domestic markets for wheat by improving food quality, variety, and convenience; and (3) finding means to upgrade mill byproducts nutritionally so that they will be more valuable as livestock feeds. Basic research on the chemistry and physical properties of wheat and wheat products supports the problem-solving projects.

Bakery arts exist at an advanced stage because they evolved over thousands of years. Only recently have the sciences developed so that systematic investigations appear likely to lead to early improvement of products and to new products. With the new scientific tools, the direction of wheat utilization research is turning more and more to basic investigations of the chemistry of wheat and the nature of its physical properties. About 40% of our domestic program is on basic research. The remainder is either closely aligned to problems of wheat processing or directed immediately toward new and improved products and processing technologies.

The PL480 program is largely directed toward basic research for the following reasons: (1) Some of the most capable scientists in the world are available and can be most efficiently used in the field of their specialization. (2) A provision of the use of the funds stresses the mutuality of benefits to both countries involved. Basic research is invariably an area of mutual interest among scientists and meets the requirement most admirably. (3) We can't expand our domestic program fast enough to get basic information needed for rational solutions to technological problems.

Twelve of the PL480 foreign grants are directly or indirectly concerned with the protein systems of wheat and their interactions with other constituents in determining the viscoelastic and other properties of dough as reflected ultimately in baking quality. Five projects seek new and better measurement and identification of proteins; four are concerned with glycoproteins, lipoproteins, lipids, and phospholipids that appear to be involved in the interactions that govern protein properties during dough mixing; two are on methods of measuring viscoelastic properties and identifying causes of differences between doughs in their flow characteristics; and one is on enzymic activity of wheat proteins. The remaining three are concerned with nutrients and their measurement relative to processing qualities of wheat. Six grants are to institutions in France, three in the United Kingdom, two in Poland, and one each in Israel, Italy, Switzerland, and Australia. These projects are under technical direction of sponsoring scientists in the Western Division, including Drs. Pence, Mecham, Binger, and Nimmo of our Cereals Laboratory, Dr. Kohler of our Field Crops Laboratory, and Dr. Neufeld, Assistant Director.

Measurement of cereal proteins. The development of bread dough and the structure of wheat bread are possible because of the unique protein that wheat contains. It is natural that we seek knowledge of wheat protein as a basis for

control of raw materials and for improvement of products and processing technologies. An important property of all proteins is the antigen-antibody reaction that develops in the bloodstream of animals. Specific antibodies develop when a foreign protein material enters the bloodstream. These antibodies react with a subsequent exposure to the specific protein. This antigenicity can serve to characterize proteins and was the basis of the immunoelectrophoresis technique innovated by Dr. Grabar of the Pasteur Institute of Paris. He is using the technique to study the protein components of wheat, barley, and barley malt under grant.[1] (See list on later page.) The electrophoresis procedure, of which you hear so much in protein research, provides a separation of soluble proteins by differences in mobility through a gel under the influence of an electromotive force. In Dr. Grabar's technique, the proteins so separated are detected in the gel by a precipitation caused by the antibody reaction. In the immunoelectrophoresis technique proteins that are soluble in water or saline solutions can be separated and identified. Dr. Grabar has found that barley and wheat contain certain protein components which give identical immunochemical reactions. Furthermore, he has found a number of wheat gliadin components that can be separated electrophoretically but react the same immunologically. Malt and barley beta-amylase were found to be immunologically identical, although the barley protein is less soluble in water and migrated more rapidly at a high pH. A protein precursor of alpha-amylase in barley malt was not found in barley, indicating a significant protein change or modification in the malting process.

One of the problems is that the protein structure and composition may be changed in the extraction process. Gluten has been particularly difficult to study because it is insoluble. As new chemical and physical techniques are devised, they are being applied to gluten. At the National Institute for Agronomic Research in Paris,[2] ultrasonic vibrations are being applied to wheat gluten for the purpose of fractionating and modifying individual constituents of the protein. It is hoped that this technique will help determine structural composition under conditions that reduce the artifacts brought about by drastic chemical solubilization procedures or at least will introduce a different type of artifact that will shed light ultimately on the molecular architecture and chemical composition of gluten molecules. The specific conditions for ultrasonic treatment have been defined already and an assessment of protein alteration is being made by chemical characterization. Altered components are being fractionated by gel filtration and electrophoresis. Thin-layer chromatography of component amino acids is being applied to identify composition of separated proteins and protein fragments.

At the University of Poznan in Poland, Dr. Wierzbowski is studying chemical composition related to enzymic reactivity of wheat proteins.[3] His particular approach has to do with the relationship of sulfhydryl groups to enzyme activity. Sulfhydryl blocking reagents are used as well as low-molecular-weight sulfhydryl compounds and oxidizing agents to modify the protein system; then proteolytic and amylolytic activities are measured. Sodium lauryl sulfate, a detergent, is also used as a reagent. It causes protein molecules to unfold and its use has revealed a relationship of masked sulfhydryl groups to proteolytic activity. Thus, as the protein molecule is in a folded or crimped position, held so at least in part by sulfhydryl bonding within the molecule, proteolytic activity exists. Unfolding by treatment with sodium

lauryl sulfate does not reduce proteolysis but subsequent sulfhydryl blocking reduces proteolysis to a much greater degree than can be accomplished by use of blocking agents with the intact enzyme. A part of the proteinase activity in flour can be activated by use of low-molecular-weight sulfhydryl compounds and inhibited by specific sulfhydryl blocking agents. Research in the Western Division indicates two types of protease proteins are found in wheat. Only one appears to have this ability to be reversibly inactivated. There is a hypothesis that oxidizing flour improvers act by inhibiting flour proteinase and these findings tend to support the hypothesis. Thus, these studies of enzyme activity of protein are shedding light on flour maturation and the nature of oxidative flour improvement.

In St. Albans, England, at the Research Association of British Flour-Millers,[4] Dr. Pace has been applying a novel method for solubilizing protein. Reactions with metallic and acidic ions such as cupric and sulfite were previously found to solubilize wool and feather proteins. Similar reactions are being adapted to study the less soluble protein components of wheat. In part, the solubilization is accomplished by rupturing disulfide bonds with sulfite. Wheat protein was solubilized with cupric ammonium sulfite but, unfortunately, good separation by starch gel electrophoresis has not yet been obtained. This work will continue and other procedures will be attempted.

Another project involves factors affecting the solubility of wheat gluten proteins. A grant has been made to the National Center for Scientific Research at Montpellier in France.[5] The effects of solubilizing or solubility-stabilizing adjuncts on bread-baking characteristics of flours are to be studied. Unfortunately, delays in laboratory construction and shortages of personnel and equipment have delayed the project.

Measurement of viscoelastic properties of dough. In addition to the chemical studies of wheat flour proteins, we are sponsoring grants involving the physical measurement of the viscoelastic properties of wheat flour doughs. Dr. Reiner at the Israel Institute of Technology at Haifa[6] is studying the basic mechanical factors which influence dough character and therefore baking properties of flours. He is developing means for reliable measurement of the various stresses and resistances to stress that are involved in the pulling, shearing, and elastic withdrawal of bread dough during mixing. He is measuring these mechanical parameters at different stages of dough mixing and correlating them with empirical data resulting from rheological behavior of dough obtained by use of the farinograph or extensograph. His very precise viscosity measurements revealed that during a short extensograph run of about 20 seconds, the apparent coefficient of viscosity of doughs decays in a very dramatic way. Thus, after a 20-second extension of a molded piece of bread dough, viscosity of the dough was reduced to less than about 1/5000th. Without the extensograph treatment, molded dough could be held up to 45 minutes without changes in these viscosity measurements. Salt content had little or no influence on viscous behavior of dough, and so the pronounced influence of salt on extensograph values must be ascribed to something other than an effect on viscosity. The intricate interrelations of rheological parameters in a dough and the continuous changes, both physical and chemical, which occur in raw material used over a number of weeks or months, during a study such as this, complicate this work. Stored flour changes, so that a series of experiments over several weeks

reflect a changing raw material in the system. Considerable pains must be taken to be certain that replicated experiments are not unduly affected by such changes in material.

The other grant supporting studies of the viscoelastic properties of flour doughs has been made to the Bread Research Institute of Australia in North Ryde, New South Wales.[7] This is related to the work in Israel but use is being made of different apparatus and techniques which are designed to measure viscoelastic properties employing a dynamic, sinusoidal loading in contrast to the measurements employing a static loading. These two projects will complement each other. Since this is a recent project there are no reports of progress. The techniques employed have not been previously used for studying dough properties and we anticipate some very interesting results. The modern methods of bread making require a greater understanding than we have today of the complex physical nature of dough and its influence on quality of bread. These two projects, one based on time-dependent transient or static circumstances of measurement and the other on frequency-dependent or dynamic conditions, should provide a much broader horizon to explore in this field.

Enzyme activity of stored wheat. In another grant to the National Institute for Agronomic Research in France,[8] a study is conducted on enzyme action at very low moisture levels in cereal grains. Major emphasis is on the lipolytic or fat-altering enzymes of wheat. Enzymes continue to act below 10% moisture content. This project seeks information on the exact relation of enzyme activity to water content of wheat, water vapor pressure, oxygen partial pressure, and temperature. This project also is just getting underway and no progress can be reported.

Protein interactions with other flour constituents. The oxidative improvement of wheat flours for bread making in modern milling and baking relieves the necessity of long-duration maturation for much of the hard red winter wheat flour that is available for bread making. One of the oxidation phenomena that has been noted in wheat components involves soluble pentosans which exist in combination with proteins as glycoproteins. These pentosans will not form gels unless they are oxidized. The changes that occur during the oxidation of pentosan glycoproteins are being studied by Professor Neukom at the Swiss Federal Institute of Technology[9] under a recent grant. In addition, he will study certain polyphenols that are associated with these glycoproteins.

The lipids of wheat and wheat flour are also believed to be involved in oxidative improvement. Very strong evidence exists for the importance of lipids in determining baking characteristics of flour. Therefore, a thorough study of lipids of whole wheat, ground wheat flour, bran, and other milling fractions is being conducted at the French School of Milling in Paris.[10] Particular attention is being paid to the fatty acid composition of wheat lipids. A number of market classes of USA wheats are being compared in the compositional studies. Total lipids are being extracted from wheat flours. The effects of addback of the extracted lipid components on alveograph measurement of the doughs are showing the importance of total lipids and of specific fractions. Defatting increases the alveograph resistance but resistance then decreases faster than normal dough especially if oxidation proceeds. This rapid loss of resistance is canceled if sulfhydryl groups are blocked in the system.

Reincorporation of unsaturated acids increases the resistance. These studies are carried out under conditions with oxidizing medium, normal medium, with and without sulfhydryl blocking reagents, and with and without the blocking of direct oxidation of proteins by means of mercuric chloride. This basic study directly supplements our own research and represents one of the most important and promising fields of investigation.

A related study is conducted by Dr. Axford at the British Baking Industries Research Association laboratories in Chorleywood, England.[11] In this study varietal differences in lipid content are being determined and correlated with baking tests.

Flours and glutens from ten USA wheats, including club, soft, hard, and durum samples are being studied for their content and type of phosphorus compounds related to lipid and protein composition at the National Institute of Agronomic Research in Paris.[12] The phosphorus in albumin type proteins is generally of a phytic nature while that in globulins is in the nucleic acid form, chiefly desoxyribonucleic acid. There is more phytic acid phosphorus in hard spring and durum flours than in hard winter wheat flour and there is less phospholipidic phosphorus and less gluten ribonucleic acid phosphorus in soft wheats than in hard wheats and durums. As this research progresses, we will learn whether these generalizations are sensitive enough to be used to predetermine baking quality of various wheat flours.

Nutrients in wheat and wheat products. The final three grants are more concerned with compositional evaluations related to nutritional quality. However, the basic compositional information of these studies may also impinge upon oxidative and other enzymes indirectly related to processing factors. For example, studies of the coenzyme role of riboflavin of wheat endosperm are being conducted at the Agricultural Higher School in Poznan, Poland.[13] Flavin nucleotides are the indispensable components of several enzymes involved in biological oxidation. The amount and form of flavins in wheat flours of different market classes of wheat and any coenzymic function of commercial importance will be determined. Experimental procedures are being developed and adapted from laboratory techniques that work very well in flavin-rich animal tissues. The relatively low concentration of flavin in flour creates a problem but progress is slowly being made.

At the University of Bologna in Italy Professor Moruzzi is studying proteins and other nitrogen compounds of wheat germ.[14] Wheat germ contains nitrogenous components of high biological value. A rational utilization of wheat germ in connection with nutrition, whether for food or feed, depends upon a better knowledge of these components than we now have. These studies have revealed the presence in wheat germ of appreciable quantities of polyamine which were not previously expected to be found there.

Finally, at Cambridge University in England, Professor Carpenter is studying the biological value of protein in wheat food products.[15] An important part of his investigation is a search for chemical methods or combinations of chemical methods that will correlate with rat and chick feeding tests for protein availability of wheat food products. The success of this work would simplify and reduce the costs of biological evaluation of wheat protein and should allow

a substantial increase in the amount of data available to help improve food products and sell more wheat. Dr. Carpenter's results indicate that protein-efficiency-ratio of wheat was improved by steeping and mild cooking as in bulgur manufacture. However, when severe treatments under high steam pressure were used, the nutritional value of the protein was reduced. A chemical analysis for "total tryptophane" has been of limited success as a chemical test for protein-efficiency-ratio for some products but did not appear satisfactory for wheat flour or wheat products. Microbial analysis for tryptophane is now being investigated to see if it would correlate better with animal feeding tests than the chemical analysis.

Conclusion. I hope you agree that the PL480 program has been very effectively used to broaden our research. All research is continuous and infinite. Individual projects seek to achieve fixed objectives. As these objectives are reached more unanswered questions are invariably revealed than we knew how to ask at the start. The PL480 research program has brought world-wide scientific resources to bear on problems of agricultural utilization. It has infused our domestic research with the vigor of broadened viewpoints. It has strengthened our efforts with pounds, francs, zlotys, marks, pesos, etc. and, more important, with the intellectual creativity of other nations.

List of Projects on Wheat

1. E9-7, Immunochemical analysis of wheat and barley proteins (Pence): P. Grabar, Pasteur Inst., Paris, France, 4-28-61 for 4 years, equivalent to $41,984.
2. E9-44, Ultrasonic study of wheat gluten proteins (Pence): L. Petit, Natl. Inst. of Agronomic Research, 6-5-61 for 4 years, equivalent to $64,941.
3. E21-1, Sulfhydryl groups in wheat (Mecham): J. Wierzbowski, Univ. of Poznan, 7-23-60 for 4 years, equivalent to $28,368.
4. E29-38, Wheat flour protein separation (Pence): J. Pace, Research Assoc. of British Flour-Millers, St. Albans, 12-11-62 for 4 years, equivalent to $72,751.
5. E9-8, Solubility of wheat gluten proteins (Pence): J. Guastalla, Research Center for Surface Phenomena and Colloidal Physica, Montpellier, 11-31-61 for 3 years, equivalent to $22,110.
6. A10-22, Rheology of wheat flour doughs (Mecham): M. Reiner, Israel Inst. of Technol., Haifa, 10-1-61 for 3 years, equivalent to $48,293.
7. O1-1, Measurement of viscoelasticity of doughs (Mecham): G. Hibberd, Bread Research Institute of Australia, North Ryde, 1-1-64 for 4 years, equivalent to $57,248.
8. E9-45, Enzyme action in low-moisture grain (Binger): R. Drapron, National Inst. of Agronomic Research, Paris, 1-1-62 for 4 years, equivalent to $50,289.
9. E27-1, Pentosans of wheat (Binger): H. Neukom, Swiss Federal Inst. of Technology, Zurich, 5-1-64 for 5 years, equivalent to $54,486.
10. E9-2, Composition of whole wheat lipids (Mecham): J. Bure, French School of Milling, Paris, 1-1-62 for 4 years, equivalent to $55,745.
11. E29-14, Wheat flour lipids (Pence): D. W. E. Axford, Brit. Baking Industries Research Assn., Chorleywood, England, 10-1-59 for 5 years, equivalent to $82,446.

12. E9-43, Phosphorus in wheat flour (Neufeld): A. Bourdet, Natl. Inst. of Agronomic Research, Paris, 6-28-60 for 4 years, extended to 6-28-65, equivalent to $64,367.
13. E21-18, Wheat endosperm riboflavin (Binger): J. Janicki, Agr. Higher School, Poznan, 9-1-62 for 4 years, equivalent to $32,968.
14. E15-31, Wheat germ proteins (Pence): G. Moruzzi, U. of Bologna, 5-29-62 for 5 years, equivalent to $62,238.
15. E29-47, Biological value of processed wheat (Kohler): K. J. Carpenter, U. of Cambridge, 2-1-61 for 5 years, equivalent to $63,160.

THE LIPIDS OF SPRING WHEAT, INCLUDING DURUM

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North Dakota State University, Fargo

As one observes those who can afford to eat steak, one often witnesses a trimming operation, whereby that exterior portion, the fat, is removed. The kernel of wheat also contains fat; however, its presence is not conspicuous. Certain portions, such as the germ, contain more fatty material, or lipid as it is more commonly called, but not to the extent where a "layer of lipid" can be trimmed off. An attempt to define lipids as a class of compounds is quite misleading, since lipids normally include those portions of biological material which are soluble in certain organic solvents, particularly chloroform. Thus the lipid extract obtained from wheat contains a variety of compounds; in fact, a variety of classes of compounds.

Extraction. Lipid researchers have tried to find a solvent system that would extract all lipids in wheat and products of wheat and yet not alter either the extracted lipid or the defatted material. Several solvents approach the extraction of lipid material as compared to acid hydrolysis, but do not necessarily leave the defatted product unchanged. In general it is necessary to add water to the organic extracting medium in order to approach 100% removal of lipids. Water-acetone mixtures, water-saturated butanol, and recently a chloroform-methanol-water combination have been used. The latter shows less change in the defatted material.

Of the nonpolar solvents, petroleum ether and ethyl ether have been the most popular. Petroleum ether in particular probably does less damage to extracted grain than other solvents but removes less of the total lipids, particularly the more polar phospholipids. Also, in cereal products such as dried dough, bread and macaroni, the lipids appear to become more "bound" and are difficult to remove. It has been reported that petroleum ether removes as little as 6% of the total lipids from some of these materials.

Methods of analysis. The several facets of chromatography have played an important role in modern lipid research. Countercurrent distribution, column, gas, and paper chromatography, and recently thin-layer chromatography have all been important in the identification of the components of the lipid fraction.

Class separation. Column chromatography has been used recently by several researchers for the class separation of lipids. The crude lipids are placed in

a glass column containing silicic acid and carried through with a series of solvents and solvent mixtures of increasing polarity. For example, the steryl esters would be among the first to be eluted from the column, and the phospholipids among the last. An example is shown in Figure 1. The lipids fractionated here were obtained from Selkirk farina by a Soxhlet extraction with petroleum ether. The graph shows milligrams of lipid residue plotted against tube number of the fraction collector.

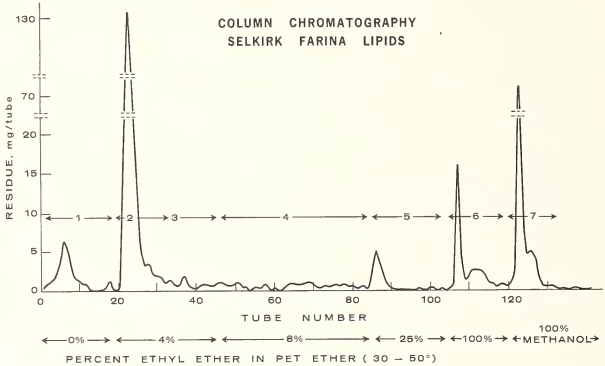

Figure 1. Silicic acid column chromatography of Selkirk farina lipids. The amount of lipid residue in each tube of the fraction collector was plotted against the tube number.

Seven fractions are noted: (1) nonpolar (principally hydrocarbons and steryl esters), (2) triglycerides, (3) fatty acids, (4) sterols, etc., (5) unidentified, (6) pigments, and (7) polar fraction. Lipids from several varieties of durum were fractionated the same way, and the same basic fractions resulted. A brief discussion of some of these fractions follow.

Nonpolar materials. The nonpolar fraction appears to contain mainly hydrocarbons and steryl esters. Several saturated hydrocarbons have been identified from wheat germ oil including both odd and even numbered carbon chains. We have done some work on the steryl ester identification using chromatographic techniques. Figure 2 is a photograph of a thin-layer plate spotted with prepared sitosteryl ester knowns along with the crude lipids of a durum and a bread wheat. A comparison of Rf values as shown in Figure 2 was one of the criteria used to identify these compounds, which are sitosteryl palmitate, oleate, linoleate, and linolenate.

It is interesting to note the different amounts of sitosteryl palmitate in the durum and hard red spring wheat. We have prepared blends of farina and semolina, extracted the lipids, and separated the sitosteryl esters using the thin-layer technique. A photograph of such a plate is shown in Figure 3.

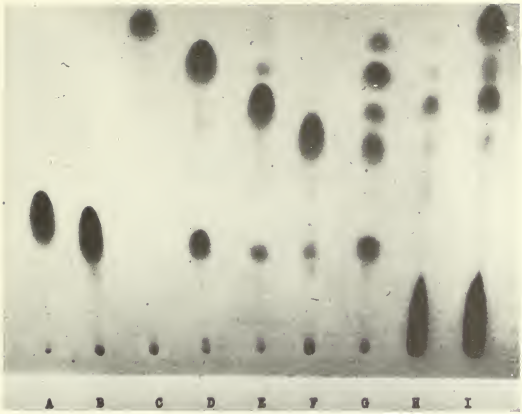

Figure 2. A thin-layer chromatoplate which shows the following: (A) methyl oleate, (B) sitosteryl acetate, (C) sitosteryl palmitate, (D) sitosteryl oleate, (E) sitosteryl linoleate, (F) sitosteryl linolenate, (G) a mixture of A-F, (H) Wells semolina lipids, and (I) Selkirk farina lipids.

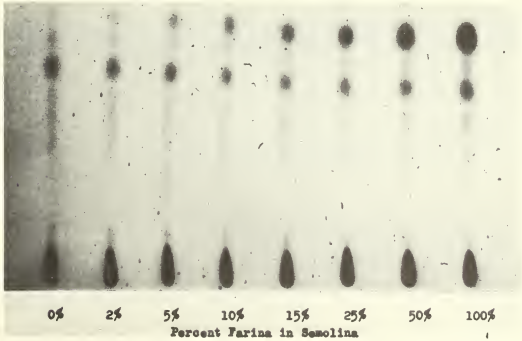

Figure 3. A thin-layer chromatoplate which shows the increase in sitosteryl palmitate (upper spot) with increase in amount of farina in mixtures containing farina and semolina. The amount of farina in the mixtures shown from left to right are as follows: 0%, 2%, 5%, 10%, 15%, 25%, 50%, and 100%.

Note the variation in intensity of the sitosteryl palmitate spots as the percentage of farina is increased in the semolina. When the densities of these spots were measured with a Photovolt Densitometer, and these values plotted against the percent farina in semolina, the graph in Figure 4 resulted.

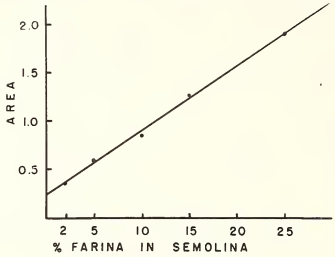

Figure 4. A graph which shows the linear relationship between the area and density of the sitosteryl palmitate thin-layer chromatoplate spot and the percent of farina contained in a mixture of farina and semolina.

Several varieties of durum, including three foreign durums, showed only trace amounts of sitosteryl palmitate. Several types of spring and winter wheats showed much larger amounts of sitosteryl palmitate than the durums. Macaroni was made from blends of farina and semolina, the lipids extracted and spotted on thin-layer plates and the results were similar to Figure 4.

Triglycerides. The general composition of the triglycerides is well known--they are made up of one unit of glycerol combined with three identical or different fatty acids (Fig. 5). However, the structure of the individual triglycerides has posed a problem. When one considers that 13 different fatty acids have been identified in wheat by more than one researcher, and 12 others by single investigators, and that perhaps all are potentially part of a triglyceride, the number of triglycerides possible becomes rather large. Some excellent work has been done in this area using countercurrent distribution, the specific action of enzymes, and specially treated thin-layer plates.

Related to the triglycerides, but actually more polar, are the mono- and di-glycerides. Their presence in wheat lipid has been reported and questioned. From very recent work in England with thin-layer chromatography the presence of both has been reported. The effect of the glycerides on wheat products has not been as pronounced as some of the other lipid fractions, particularly the polar lipids. However, the addition of monoglycerides to semolina has been shown to give an improved product.

Fatty acids. Fatty acids exist in bread flour and semolina in the free form as well as in the esterified form. The measure of free fatty acid content of flour has been used as a measure of rancidity in flour. The different kinds of fatty acids found free are roughly the same as those which are in the esterified form. Linoleic acid is the most abundant unsaturated acid, as well as the

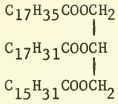

Figure 5. A triglyceride

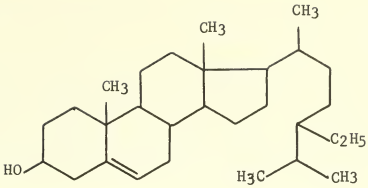

Figure 6. Sitosterol

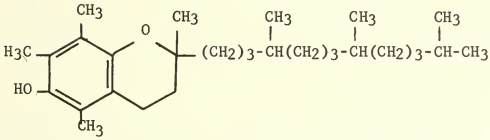

Figure 7. Alpha-tocopherol

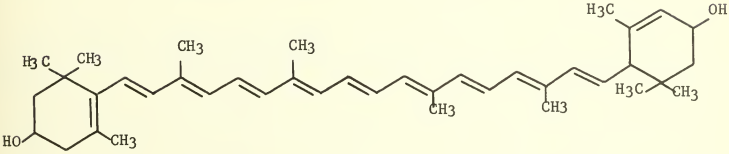

Figure 8. A xanthophyll

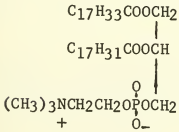

Figure 9 (left). A lecithin (phospholipid)

most abundant of all the acids, while palmitic is the most abundant saturated acid. Durum lipids show this same pattern, but when compared with spring wheat, less linoleic and more oleic acid are found in the durum lipids. Linoleic and linolenic acids appear to play a role in the improving action that takes place in bread and cake flours through age or through oxidizing agents. Also, it has been reported by several authors that chlorine bleach in flour affects the

lipids including the double bond structure of the fatty acids, while chlorine dioxide bleach does not.

Sterols and tocopherols. Several sterols have been identified in wheat lipids, but because of the similarity of this class of compounds, there are probably several more that have not been identified. The most common plant sterol is sitosterol (Fig. 6), which probably constitutes 70% of the total sterol composition. Durum has been reported to contain more free sterols than bread wheat flour. Few studies have been made as to the effect of sterols on the quality of wheat products.

The sterols are often referrred to as "unsaponifiable material," in that they are not subdivided when attacked by alkali. Another class of compounds which can be described as "unsaponifiable" are the tocopherols (Fig. 7), or vitamin E. Four of these compounds have been identified in wheat lipids, although they are not all active as vitamins. They have been of interest because of their activity as antioxidants in flour. It is known that bleaching by chlorine dioxide has an adverse effect on the role of the tocopherols as anti-oxidants.

Pigments. Only trace amounts of carotene have been reported in wheat. The xanthophylls (Fig. 8) and flavones are probably responsible for most of the yellow color one sees. This color is met with mixed emotions. For bread and cakes, the housewife wants flour to be white, and so it is bleached. On the other hand, this domestic dictator desires colored semolina dry goods, and so color is highly desirable in semolina.

Polar fraction. The last fraction one obtains in a polar separation is a complex mixture containing such items as the phospholipids (Fig. 9 is an example), glycolipids, and the cerebrosides. One who works with these materials is plagued first with difficulty of their extraction and also with decomposition, since many of the components are unstable. Yet, considerable work has been done in identifying these compounds, and much evidence has been found to point out that they have a definite effect on quality. We have found through column chromatography that Selkirk whole wheat lipids and durum whole wheat lipids (both petroleum-ether-extracted) contain about the same amount of the polar fraction. However, when the purified farina and semolina lipids are chromatographed, the Selkirk polar fraction doubles in amount while the durum stays approximately the same.

Conclusion. At least 75 compounds have been isolated from the lipid fraction, not counting the possible combinations of fatty acids with triglycerides and phospholipids. More information is being sought concerning the chemical composition of the lipids of wheat and durum, and their relationship to quality. With better knowledge and understanding of the biochemical foundation of wheat and durum (those compounds that make up its entirety), we will better be able to produce high quality raw materials for higher quality products and thus witness greater utilization.

HARD WHEAT COMPOSITION AS RELATED TO UTILIZATION IN BREAD-MAKING

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The Kjeldahl protein test is considered the best single test of protein quantity. Protein content of wheat permits evaluation of a major part of the inherent bread-making potentialities of wheat flour. It is generally realized, however, that wheat flours that contain the same amount of protein may perform differently in baking. Bread-making potentialities are slightly higher in preripe wheat than in the same wheat allowed to mature completely in the field. At the same time some millers and bakers maintain that freshly harvested wheat is improved if stored prior to processing into flour and bread. Wheat flour bakes poorly if milled from wheat grown under adverse climatic conditions, if harvested at too high a moisture content, or if stored under suboptimal conditions. Changes may occur, yet with no detectable difference in Kjeldahl protein content. But even sound wheat flours containing the same protein content, but milled from different varieties, vary substantially in mixing time and tolerance, oxidation requirements, fermentation requirements and tolerance, oven spring, and loaf volume. Difference between rheological properties and bread quality, predicted on the basis of Kjeldahl protein determination from actual bread-making performance, is generally attributed to a catchall property called protein quality.

Many methods have been proposed to assess this quality. These include simple chemical tests, physico-chemical determinations, use of physical dough testing devices, and of course actual bread-baking tests. The gluten test and methods of testing gluten quality are widely used in Europe. Protein solubility, imbibition, and peptization are some of the physico-chemical tests proposed to evaluate wheat protein quality. They are useful and simple tests, capable of distinguishing between wheat flours varying widely in bread-making quality. Amino acid composition, N-terminal, C-terminal amino acids, and preliminary studies of amino acid sequence have provided useful information on the nutritional value and on the "chemical" formula of wheat proteins, but have been, so far, rather disappointing in explaining differences in bread-making characteristics of wheat varieties and types grown in common or different environments.

Important questions in the chemistry of wheat proteins in general, and of high-molecular-weight wheat gluten in particular, concern the type of bonds that hold polypeptide strands together and the nature of intermolecular crosslinks responsible for gluten structure. Considerable progress is being made in discovering and elucidating the nature of probable crosslinks in a variety of biological systems. This has resulted in an impressive accumulation of information and has contributed to our understanding of physical properties of biological systems, effects of hydration, mechanical treatment and oxidizing agents on the systems. Only a start has been made in understanding the role of various links in wheat proteins and in correlating rheological properties of wheat dough with the structure of gluten proteins. This paper is largely a review of recent work at Kansas State University.

Studies on wheat proteins. The oxidation requirements of white wheat flour are substantially lower than those of dark flour milled from the same wheat but containing large amounts of particles originating from the aleurone layer or the germ. Oxidation requirements depend to a large extent on the levels of SH-containing proteins. Outer layers of the wheat endosperm, of the germ, and of the aleurone layer are rich in SH-containing proteins. A closer look at a wheat section under higher magnification shows the high SH concentration in the outer layers, around the crease, and in the germ, and it explains some of the differences in oxidation requirements of flours varying in extraction rate.

Rheological properties of dough can be modified dramatically by minute amounts of reducing agents such as sodium bisulfite, by thiol-containing amino acids such as cysteine, or by oligopeptides such as reduced glutathione which contains a free SH group. If however we add SH-containing proteins which have a molecular weight of 10,000-100,000, i.e. thiolated gelatin, the extent of modification is much smaller. The rate of modification by the high-molecular (100,000) Thiogel B is much smaller than that of Thiogel A, which has a molecular weight of 10,000, and the effects of both are much smaller than that of glutathione, despite the addition of all three compounds on an equal SH-content basis. Not only does the effect depend on the molecular weight of the SH-containing compound, but the reversibility of the modification, by adding excess oxidizing agents, depends on the extent of modification resulting from the action of the reducing agent. Similarly, glutathione decreases loaf volume and impairs loaf characteristics much more than an equal amount of thiols added in the form of a high-molecular gelatin. The limited effect of thiolated gelatin seems to result from the association of Thiogel with wheat gluten. It is clear, therefore, that meaningful interpretation of the role of sulfhydryl and disulphides in forming gluten structure should be based on studies that employ thio-containing high-molecular proteins, preferably from wheat gluten.

Sulfhydryl and disulfide-containing amino acids constitute only about 1 to 2% of the wheat-protein amino acids. While the relatively small amount of cysteine and cystine in the large wheat protein molecule does not exclude their significant role, it has recently become evident that the reactivity of sulfur-containing groups of wheat proteins explains only some features of dough rheology. Attention has therefore been directed to some of the major wheat protein components. While not as reactive as SH-containing amino acids, they were found to exert an important cumulative effect as a result of contribution of small forces by a large number of less reactive amino acids. Nearly one-fourth of wheat nitrogen is amide nitrogen. Indirect evidence based on the ammonia determined in acid-hydrolyzed wheat proteins (the amino acids of which have been fractionated by the amino acid analyzer) shows that glutamine accounts for most of the wheat amide content. The amide content can be determined directly if the wheat proteins are hydrolyzed by a proteolytic enzyme. Samples were hydrolyzed with either hydrochloric acid or with a protease of very broad specificity. Amino acids in hydrolyzates were separated by two-dimensional paper chromatography. Analysis of gluten, gliadin, glutenin, and of wheat protein isolated by the Hess flotation method showed that glutamic acid was present in wheat proteins predominantly as glutamine, and aspartic acid predominantly as asparagine. The fact that wheat proteins contain such an unusually high glutamic acid content and that glutamic acid is present in the protein

molecule mainly as amide, seems to impart to the macromolecule a definite structure and characteristics and seems somehow related to the unique bread-making properties of wheat flour.

Partial hydrolysis of proteins by proteases having a specific action and isolation of the macromolecular fragments have been shown to be useful tools in protein characterization. What happens if such enzymes are added to wheat flour? We investigated the effects of a number of proteases on rheological properties and on bread quality. The enzymes employed included three pure crystalline proteases, a nonspecific endopeptidase from B. thermoproteolyticus, an enzyme from Streptomyces griseus, which combines endo- and exo-peptidase action of broad specificity, and trypsin with a specific endopeptidase action involving the carboxyl groups of the amino acids lysine and arginine. Additionally, we tested the effects of three commercial protease mixtures of fungal origin from Aspergillus niger and A. oryzae. All enzymes were added on a comparable basis of proteolytic activity measured by the hemoglobin method. Even minute levels of the enzyme from B. thermoproteolyticus reduce loaf volume dramatically. The enzyme from S. griseus shows a gradual linear response. Trypsin shows little action at low levels of added enzyme; the decrease in loaf volume takes place only at high levels of enzyme, after extensive hydrolysis at sites of enzymatic breakdown. We are continuing these studies with additional enzymes and hope that a comparison of the action of the enzymes on bread quality with their effects on fractionation of purified wheat proteins will provide information on the importance of protein moieties and their structure in bread making.

One of our main problems in studies of wheat proteins is that the manner used to isolate proteins from the grain tissues or wheat flour and the methods used for preliminary fractionation may profoundly affect the material being investigated. We have therefore evaluated critically some of the factors in protein isolation, which may affect protein characterization. Salt-soluble proteins were extracted from hard red winter flour at pH 7.0, and gluten proteins with acetic acid at pH 3.0, as well as with solutions containing N-ethylmaleimide (NEMI) and urea, or combinations of both.

NEMI is an effective though not completely specific SH-blocking reagent. That hydrogen bonding plays an important role in biology, both with regard to protein structure and with regard to types, mechanisms, and rates of protein reactions is well established. Without hydrogen bonding, the relatively easy rotation around many of the bonds in the polypeptide chain would result in a high degree of conformational randomness. The energy required to break a hydrogen bond is usually in the range of 5-10 KCal per mole, compared with 50-100 KCal per mole for ordinary covalent bonds. Hydrogen bonds are thus easily broken. At ordinary temperatures, however, an exchange reaction takes place, during which new hydrogen bonds are simultaneously formed.

The isolated proteins were fractionated by gel-filtration, polyacrylamide gel electrophoresis and sucrose-gradient ultracentrifugation. Gel-filtration is a new procedure in which, to a large extent, separation is based upon differences in molecular size. The filtering material used in our experiments was Sephadex, a commercial product consisting of small grains of insoluble material made by crosslinking a polysaccharide, dextran; Sephadex is

manufactured in five degrees of crosslinkage. We used G-100 and G-200 which are best suited for fractionation of the high-molecular wheat proteins. In gel-filtration on Sephadex columns, one takes advantage of the differential permeability of the porous modified dextran beads to molecules of different sizes. Molecules small enough to penetrate into the beads are delayed and washed through the column more slowly than big molecules which do not penetrate the dextran gel.

Electrophoresis is one of the most effective methods for the separation of ionic components of a mixture. The method is based on the fact that proteins in solution are generally charged and migrate in an electric field. The electrophoretic mobility depends on the magnitude of the net charge on the protein ion but is affected also by the frictional resistance exerted on the protein by the medium. The latter effect depends in a complex manner on the shape and size of the protein molecule and the extent to which it is solvated. Many experimental techniques and devices have been utilized in studying electrophoretic behavior of proteins. Excellent resolution has been achieved when advantage is taken of the frictional properties of gels, such as starch gel, to aid in separation by sieving at the molecular level. A new method, polyacrylamide gel electrophoresis, takes advantage of the adjustability of the pore size of a synthetic gel. The gel is translucent, and the separated protein fractions can be evaluated by photodensitometry after staining. High resolution is achieved within a short time.

If a protein solution is centrifuged at high speed, the proteins which are of macromolecular size tend to sediment, with the result that their concentration increases from the center of the centrifuge to the periphery. The sharpness of the sedimenting boundary obtained in an ultracentrifuge is frequently used as a criterion of purity, and the rate of movement of the protein outward from the center of rotation, a measure of the molecular weight of a protein. This method was developed in 1925 by Svedberg, who invented the ultracentrifuge. The presently used modications of the ultracentrifuge employ speeds as high as 60,000 rpm. and develop centrifugal fields of the order of 500,000 times gravity. Sucrose gradient centrifugation is a recently developed method of equilibrium ultracentrifugation for the study of macromolecules. This procedure improves the quantitative analysis and resolution of proteins varying in structure, composition, and molecular weight. Wheat flour proteins differ widely in amino acid composition, molecular weight, size, shape and structure. Consequently a combination of methods must be employed in their studies.

Based on separation according to average molecular weight on Sephadex columns up to 8 fractions were isolated. It was found on basis of gel filtration, electrophoresis, and ultracentrifugation that characterization of proteins on basis of their solubility in arbitrarily selected solvents was unsatisfactory. Proteins isolated by each solvent system contained a heterogeneous mixture of moieties. The isolated protein fractions showed aggregation and disaggregation phenomena. The results indicated that the low molecular weight proteins were capable of modifying and reacting with the large gluten proteins. These findings strengthen the present concept of the role of water- and salt-extractable proteins in dough structure. Hydrogen bonding and reactivity of free thiol and of disulphide groups were found to affect the

relative distribution and average molecular weight of wheat proteins isolated from the source and fractionated by molecular sieves or other fractionating systems.

Understanding of the unique and complex gluten proteins is an integral part of the study of inherent differences between wheat flours which vary in oxidation requirements, rheological properties, and overall breadmaking potentialities. During the last 20 years considerable progress has been made in elucidating the role of protein sulphydryl and disulphide groups and their interchange in bread making, in general, and in flour maturing and oxidation, in particular. Recent studies on isolated wheat proteins point to the importance of hydrogen bonding, aggregation and disaggregation phenomena. Hydrogen bonds were found, recently, to play a major part in determining solubility of wheat proteins, visco-elastic properties of doughs made from wheat flour, and actual performance in baking. A great deal more must be learned about wheat proteins, their structure and interaction with other wheat components such as lipids and carbohydrates before the physical properties of dough and its baking behavior in terms of the chemistry and reactions of wheat flour components can be understood. Availability of new and better biochemical and biophysical technics furnishes us with new tools to probe into the nature of wheat flour components and their role in breadmaking.

Summary. The role of wheat proteins in breadmaking was studied by histochemical methods involving localization of SH-containing proteins in the wheat kernel, and determining the effects of SH-containing amino acids, oligopeptides and proteins varying in molecular weight on rheological properties of dough and on bread quality. Separation of enzymic and acid protein digests by two-dimensional paper chromatography established in a direct way that glutamic and aspartic acids were present in the wheat protein predominantly in the amide form. The effect of pure proteolytic enzymes of known action was found a useful tool in the study of protein moieties essential for maintaining bread quality. The importance of sulfhydryl groups and hydrogen bonding in isolation and fractionation of wheat proteins was correlated with their effects on rheological properties of wheat dough and bread quality.

EXPLORING THE STRUCTURE OF PROTEINS IN WHEAT GLUTEN

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The gluten of wheat has long been recognized as making a major contribution to the usefulness of wheat flour for bread baking. The elastic cohesive properties of dough reflect the characteristics of the gluten complex formed during dough mixing. Because gluten consists primarily of protein, the properties of gluten point to unique characteristics of the proteins of wheat and suggest that wheat flour should have industrial as well as food uses which would depend on these particular proteins. One important aspect of utilization research involves exploring the structure of these gluten proteins.

Before seeing how such research is progressing, some aspects of the nature, philosophy, and technique of exploration need to be understood. Exploring involves striking out into the unknown. The explorer has a broad goal: a territory which he expects to make known to others by maps and descriptions. He may have some preliminary ideas about the nature of the territory. First he must decide where to start and in what direction to proceed. In most cases there will be more than one starting point and there will be several directions, depending on the experiences and views of the explorer. He may move slowly or rapidly depending on how rough the terrain or how dense the forest. Often he will retrace his steps and repeat measurements to ensure accuracy of his map. Often he will look ahead and take notes on geographical features or outcroppings of rocks. Then as he forges ahead and looks more closely he will confirm, or he may change, his initial comments and impressions, filling in details of what he had earlier described in a broad way.

Cereal chemists are exploring the wheat proteins and their structures. They are detailing a description of the area through which they are traveling. In many cases, these chemists start at different points and follow different directions. Sometimes their investigations overlap, thereby giving even more dependable knowledge. Sometimes in using different tools they expand and complement the results of the other explorations. Today I shall review some of the exploring being done by cereal chemists at the Northern Regional Research Laboratory.

In studying structure of the proteins in wheat gluten, we look for a number of things. We need to see how many kinds of molecules are present; how big they are, and what their shape is; what physical forces hold them together; and what chemical ties are present in the molecules. Ultimately, the location of all amino acids, or at least those functionally important, must be determined. All these features and others have a bearing on the properties of the mixture of proteins in wheat gluten. In fact, these factors are so numerous that not all can be considered now. An example of those omitted is the effect of other kinds of molecules on the gluten proteins. Here I am referring to the interaction between the gluten protein and lipids, phospholipids, and possibly carbohydrates.

The studies I shall review are concerned primarily with advances we have made in separating gluten proteins, determining structural function of disulfide bonds as related to both molecular size and molecular shape, and establishing relationships between the gliadin and the glutenin fractions of gluten. First, we should take a look from afar at the material (Fig. 1). Hydrated gluten stretches, shows elasticity, and at the same time possesses some flow properties. A rather narrow range, quantitatively, of these properties is essential for optimum performance of a flour in bread making. One of the ultimate goals which we and others have is to explain why wheat gluten has these properties and what factors influence the properties quantitatively.

As we have moved into the strange land of wheat gluten proteins, one of our surveying instruments has been starch gel electrophoresis. With it, we can begin to see something of the number and some of the characteristics of the individual proteins making up wheat gluten. In Figure 2 we have a pattern of gluten itself and of the two fractions into which it can easily be separated:

Figure 1. Whole gluten, hydrated, is elastic and cohesive.

Figure 2. Starch-gel electrophoresis of gluten and the gliadin and glutenin fractions.

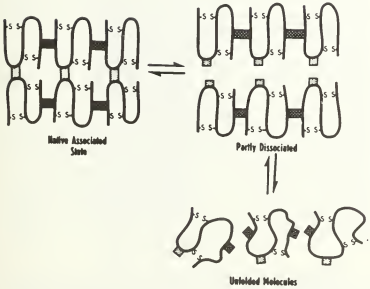

Figure 3. Association and dissociation of protein molecules.

Figure 4. Starch-gel electrophoresis pattern of gliaden and glutenin before and after reduction.

namely, the alcohol-soluble gliadin and the alcohol-insoluble glutenin. In the pattern for whole gluten notice particularly that there are a number of bands which indicate the presence of distinct components differing in the charge carried by the molecules. Another feature is the presence, at the bottom of the gel, of a dark band, indicating that a considerable amount of protein remained at the starting line. This portion has molecules too large to move through the starch gel.

When we look at the gel patterns of gliadin and glutenin we see that the gluten proteins have been separated fairly well into two classes with respect to behavior on starch gel. Essentially all the gliadin fraction has moved into the gel, yielding bands identical with those in the pattern for whole gluten. Very little if any protein remained at the starting point. On the other hand, essentially all the protein in the glutenin fraction remained at the origin, having been unable to penetrate the gel. In this study we reached the preliminary conclusion that the gliadin fraction is made up of a number of relatively low-molecular-weight proteins, whereas glutenin has molecules of much higher molecular weight. We cannot say at this point whether the glutenin molecules are all alike or include several kinds. Our conclusions have been confirmed by exploration with other instruments to determine molecular weight and other properties.

At this point we should consider the philosophy of what we call a "molecule" and give recognition to the fact that molecules may aggregate or stick together. The aggregation and disaggregation of protein molecules are depicted diagrammatically in Figure 3. Each solid line represents a chain of amino acids joined together by peptide linkages. These solid lines correspond to the ultimate chemical units which one can hope to obtain without chemical breakdown of the protein. Strictly speaking, at least from my viewpoint, these are the molecules of protein.

In many proteins, however, and certainly it is true with the proteins of wheat gluten, there is a strong tendency for these molecules to adhere to one another. The forces holding one molecule to another are depicted by the shaded areas in Figure 3. Some of our studies, which I discussed briefly at last year's conference, indicate that the physical binding forces in gluten proteins are largely hydrogen bonds involving the amide groups of the abundant glutamine residues in these proteins. As suggested by the difference in shading in Figure 3, there may be more than one type of these physical or secondary binding forces. Thus far our exploration has put primary emphasis on individual molecules of the protein. However, I recognize and wish to emphasize that many properties of gluten may depend upon secondary binding forces and upon the aggregation and interaction of the protein molecules. We find, for example, that modification of the amide groups through chemical treatment weakens hydrogen bonding and simultaneously destroys the cohesive elastic properties of the wheat gluten complex.

Another type of binding that may be present is depicted in Figure 3. Disulfide linkages (-S-S-) are shown as forming bridges within the individual chains of amino acids. These disulfide bonds hold the molecule in a folded or looped shape. Another type of disulfide bonding also can occur. This linkage would be from one chain of amino acids to another. In other words, one could

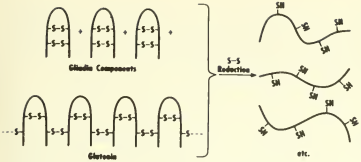

Figure 5. Schematic drawing of disulfide bonding and cleavage by reduction.

A B C D

Figure 6. Starch-gel electrophoresis patterns of (A) original preparation and (D) purified gliadin and of impurities removed (B and C).

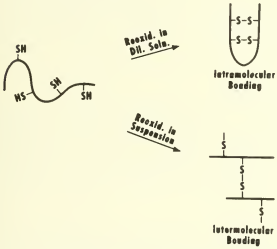

Figure 7. Changes in reduced gluten protein molecule on reoxidation.

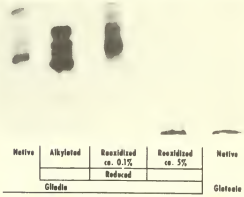

Figure 8. Starch-gel electrophoresis pattern after reduced gliadin is reoxidized in dilute and concentrated solution.

Figure 9. Starch-gel electrophoresis patterns comparing reduced gliadin and reduced glutenin, not alkylated.

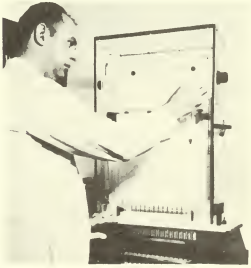

Figure 10. Apparatus used for separation by continuous-flow electrophoresis of the type called "hanging curtain."

replace the crosshatched physical binding by a disulfide bond, thereby giving a chemcially linked aggregate which we more properly, then, would call the molecule. Both types of disulfide bonding exists in wheat gluten protein and account for some of the differences among the proteins.

These disulfide bonds can be broken, for example, by reducing agents. Incidentally, such treatment also destroys the elastic cohesive characteristics of gluten protein. Figure 4 shows what happens to the starch gel electrophoresis patterns when one breaks the disulfide bonds of gliadin and glutenin by reduction and then carries out the gel electrophoresis. The more dramatic change is observed for the glutenin fraction. Whereas the original glutenin failed to migrate into the gel, the reduced glutenin not only migrates almost completely, but also separates into a number of different bands indicating that the fragments liberated by cleavage of the disulfide bonds are structurally different. The ability to migrate reflects a transformation to a much lower molecular-weight material.

In the case of gliadin, reduction causes little or no difference in the number and relative intensities of the bands, but all the protein moves more slowly in the starch gel. Our various studies indicate that this slower movement is a result of changing the shape of the molecule rather than its size, and that the molecules do not move as easily through the starch gel because of this change in shape.

A diagrammatic comparison of disulfide bonding for gliadin components and for glutenin is given in Figure 5, along with an indication of the effect of breaking disulfide bonds by reduction. Gliadin components are individual chains of amino acids with internal disulfide crosslinkages that hold the molecule in a folded or rather globular shape. Cleavage of the disulfide bonds allows these molecules to unfold and stretch out but, obviously, without any change in molecular weight. The more extended molecules logically would have greater difficulty in moving through the pores of a starch gel. On the other hand, glutenin has one chain of amino acids united to the next by disulfide linkages. At the same time, some or all of the individual chains of amino acids may have internal bridges, again giving a folded or looped structure. In this instance, cleavage of the disulfide bonds not only permits unfolding, but also breaks apart the large molecule into small ones corresponding to the individual chains of amino acids.

We recently have made progress in separating individual components of the wheat gluten protein mixture. This separation has been accomplished by the use of column chromatography on the commercial product Sephadex. This material is in the form of small particles which are porous but which have very small pores, actually in the range of the size of the molecules about which we are talking. Chromatography on Sephadex permits one to make separations, at least roughly, on the basis of molcular size. The application of this technique has given us further indications of the nature and variety of molecules in gliadin.

Column chromatography on Sephadex was used to separate gliadin into three fractions. The starch gel electrophoretic patterns of the original gliadin and of the three fractions are shown in Figure 6. On the left is the original gliadin, and one should notice particularly that there is considerable

background darkening in the region of the individual bands and extending down to the starting line. The first fraction to come off the Sephadex column should be the material of highest molecular weight. Its pattern (second from the left) is characterized by diffuseness extending down to the starting line and by relatively little evidence of the formation of distinct bands. When subjected to cleavage of disulfide bonds by reduction, this fraction underwent changes similar to those in the glutenin fraction. After reduction it gives discrete bands which correspond fairly well to the bands obtained on electrophoresis of the reduced glutenin. We can conclude that this fraction is comparable to glutenin because it has a high molecular weight as a result of disulfide cross-linkage; however, it differs in being soluble in alcohol. This variance may be a result of either intermediate molecular weight or having been virtually "dragged" into solution by the accompanying gliadin protein. We are in the midst of further study of this fraction to obtain more information on its molecular weight and relationship to the rest of the glutenin.

On the other extreme, the last material to be removed from the Sephadex column gave the pattern on the far right of Figure 6. The outstanding characteristic of this pattern is the distinctness of bands as a result of removal of material which gave the background darkening in the whole gliadin. The individual bands correspond to those in the original gliadin both in position and in relative intensity. The intermediate fraction gave the pattern second from the right. This material probably is of smaller molecular weight than the first fraction and, at the same time, contains at least some of the material characteristic of the purified gliadin.

The results of this fractionation suggest that we may have an alternative basis for classifying the proteins in wheat gluten. One class of proteins would be made up of molecules represented by purified gliadin, which contains single chains of amino acids held in loops by disulfide bonds. The other class of proteins would be those of higher molecular weight and capable of being broken down into smaller fragments by reductive cleavage of the disulfide bonds. We see from the results of the Sephadex separation that although such a classification does correspond roughly to the separation into gliadin and glutenin by solubility in alcohol, the solubility characteristics are not definitive since part of the higher molecular-weight material "overlaps" into the gliadin fraction.

Our exploring of the disulfide linkage and their relationship to structure has carried us into another area. As shown in Figure 7, disulfide linkages can be formed anew by oxidation of the reduced material. If the oxidation is carried out in a dilute solution, disulfide linkages will be predominantly within individual chains of amino acids, and the resulting structure is reminiscent of that assigned to gliadin. On the other hand, oxidation in a concentrated solution or in a suspension gives disulfide linkages between chains, with a resulting increase in molecular weight. Here the structure is reminiscent of that assigned to glutenin. We have carried out such oxidation under the two conditions, and the results are demonstrated by starch gel electrophoresis in Figure 8.

The gel pattern for native gliadin is shown on the far left of Figure 8. The pattern marked "alkylated" is the reduced gliadin in which the disulfide bonds have been broken and the resulting sulfhydryl groups blocked chemically by alkylation in order to stabilize the structure. The number of bands and their rate of movement in the gel are the same as for the reduced gliadin.

Oxidation of reduced gliadin in a dilute solution gives the gel pattern shown in the center. For all practical purposes this pattern is identical with that of the original native gliadin. We have other evidence which supports our belief that we have in this instance actually restored the original structure. We also know that both reduction and oxidation must be carried out under proper conditions if the original structure is to be restored successfully. On the other hand, the product of oxidation in concentrated solution has a gel pattern closely resembling that of native glutenin. This pattern (Fig. 8) indicates that high-molecular-weight crosslinked material has been formed.

One important line of evidence for restoration of the original gliadin molecules by oxidation in dilute solution has been given by immunological studies (Table 1). These results were obtained by Professor Heiner at the

Table 1.--Immunological properties

Protein	Active antigens found	Gliadin I antigen
Gliadin	2	+4
Reduced alkylated gliadin	0	0
Reduced gliadin-reoxidized at 0.1% concn.	2	+3
Glutenin	2	+1
Reduced gliadin-reoxidized at 5% concn.	1	+1

University of Utah. He has prepared serum containing antibodies specific for gliadin. In this example there are two active antigens. One, designated as Gliadin I antigen, shows an activity of plus four, a very high activity. The reduced alkylated gliadin, however, shows no antigenic activity. On reoxidation of the reduced gliadin in dilute solution, both number of active antigens and level of activity for the Gliadin I antigen are restored. Glutenin also showed two active antigens, but the Gliadin I antigen had quite low activity. The reduced gliadin, which had been reoxidized at high concentration, was comparable to the glutenin in terms of Gliadin I antigen activity but differed in having only one active antigen.

Last year we suggested that there might be the same amino acid chains in glutenin as there are in the individual components of gliadin. This was based on the observation, Figure 9, that bands of protein in reduced glutenin had counterparts in terms of rate of movement in the reduced gliadin. However, there were marked differences in relative amounts between the components of reduced gliadin and reduced glutenin. This is an example of impressions reported after the first glimpse of a landmark but which require modification on a closer examination. We now have evidence pointing in the other direction, but we still are reluctant to draw a final conclusion. At any rate, the following reoxidation studies on reduced glutenin in dilute solution gave results different from those obtained with reduced gliadin.

You will recall from Figure 8 that when the reduced gliadin was oxidized, the rate of migration in the gel was restored to its original higher value. In contrast, our limited trials on the reoxidation of reduced glutenin in dilute solution caused no change in the rate of electrophoretic movement of some components in the gel. Another difference was in the ease of oxidation. Reduced glutenin oxidized much more slowly than the reduced gliadin. Much more

exploration is required before we know precisely what the differences are between the reduced gliadin and the fragments produced by reduction of glutenin. The important point is, we now believe that there are differences between the two.

We have made significant progress in separating individual components, both of the original gliadin and of the reduced glutenin. I already have mentioned the use of chromatography on Sephadex. We are also using successfully other forms of chromatography. Still another technique (Fig. 10) is hanging curtain electrophoresis. As many of you know, this technique combines a downward flow of buffer solution and a crosswise application of electric current. The current moves the proteins sidewise while the movement of the buffer carries them down the sheet of paper. The protein solution is applied at one spot in the upper right-hand corner. The sheet has a number of points at the bottom, each of which delivers drops of buffer into individual test tubes. The individual proteins that are moved sidewise at different rates then take a diagonal path down the paper and the points at which they appear along the bottom depend upon the relative rate of migration under the influence of the electric current. In this way the proteins are separated more or less completely into individual tubes or groups of tubes at the bottom. By combining various methods of separation, we have been able to prepare one component of the gliadin in quite pure form, and we have made progress on the separation of the other components.

The component we have isolated is the one known as gamma-gliadin. In the gel electrophoresis pattern in Figure 11 we see that the behavior of the fraction shows good removal of the other components characteristic of native gliadin. We also see the effect of reductive cleavage of the disulfide bonds and of reoxidation in dilute solution. The important point about the reduced alkylated material is that we still have only one band in the gel pattern. This band agrees with the concept that the disulfide bonds in the gliadin component simply hold two portions of the single chain of amino acids together. Reoxidation restores the original rate of movement in the gel, again indicating that under these conditions the original structure is restored.

With a reasonably pure component available, we were then in a position to make a more critical study of molecular weight. This was done by the use of the analytical ultracentrifuge in which a solution of the protein is centrifuged at such a high rate of speed that the particles or molecules move toward the bottom of the cell. For the most critical measurements the speed of the centrifuge is adjusted so that we obtained an equilibrium condition in which the diffusion of the protein molecules toward the top of the centrifuge cell was balanced by the gravitational force, giving a steady state of change of concentration of the protein from the top to the bottom of the cell. In Figure 12 the type of data we obtained on gamma-gliadin is plotted. This particular procedure easily shows up any tendency of the molecules to aggregate to form larger particles. When all the molecules are the same size, we got a straight line as shown by the points for the solution in aqueous guanidine hydrochloride. On the other hand, the solution in aluminum lactate buffer gives points which depart from the straight line and which correspond to a curved line. Although the amount of aggregation was quite small, there obviously was some. As I mentioned earlier, we recognize that such aggregation is very important to the

Figure 11. Starch-gel electrophoresis pattern of the separated gamma-gliadin component and its reduced (alkylated) and reoxidized forms.

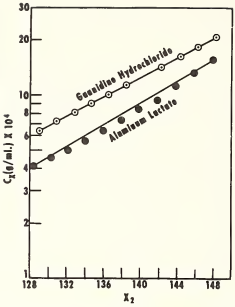

Figure 12. Sedimentation equilibrium data on gamma-gliadin in two solvents.

Figure 13. Starch-gel electrophoresis patterns of chromatographically separated fractions of reduced cyanoethylated glutenin.

Figure 14. Hydrated gluten and its gliadin and glutenin fractions.

overall properties of gluten. However for the particular studies with which we were concerned at this point, we sought data on individual molecules. Calculating our results over to a molecular weight indicated a value in the neighborhood of 30,000 for the gamma-gliadin.

Still another characteristic of protein molecules is their shape. We have explored this feature further for gliadin, with particular attention to the effect of cleavage of the disulfide bonds and to their restoration by oxidation. One aspect of our results is shown in Table 2. The technique of

Table 2.--Optical rotatory dispersions of gliadin solutions (expressed as Moffitt-Yang parameters)

Gliadin preparation	a_0	b_0	Helix* %
Native	-575	-105	15.9
Reduced-alkylated	-694	0	0
Reduced-reoxidized	-628	-100	15.3

* 100% helix, b_0 = -660; λ_0 = 212 mμ.

optical rotatory dispersion was used, in which effect of the protein solution on polarized light depends, in part, on the shape of the molecule and, more specifically, on the extent to which the molecule has a helical shape. Without going into the details of method of measurement and calculation of data, I call your attention to that column which is headed "Percent helix." The native gliadin preparation had about 16% of the protein molecule in the helical form. Reduction completely destroyed the helix, whereas reoxidation in dilute solution restored the proteins to approximately the same percentage of helix as was present originally. These data suggest that the disulfide crosslinkages within the gliadin molecules restrained the molecules so that they were held in a shape which permitted the existence of about 16% helical form. Cleavage of the disulfide bonds then allowed the molecules to unfold and stretch out with resulting destruction of the helical form. The return to essentially the original value on oxidation is another line of evidence supporting our statement that we have actually restored the gliadin to its original state.

Now let us take a quick look ahead to see where our exploration is taking us. One of our investigations is the separation of the fragments produced from glutenin by cleavage of the disulfide bonds. In Figure 13 we see the results of applying chromatographic fractionation to reduced glutenin stabilized by forming the cyanoethyl derivative of the sulfhydryl groups. This gel electrophoresis pattern shows that the three fractions which we obtain represent a good start toward separation, at least into pairs of electrophoretic components. As we isolate individual components, both from the reduced glutenin and from the gliadin, something we expect to study is the location of the amino acid responsible for the disulfide linkage. This aspect is of interest because of the obvious importance of these disulfide linkages to the properties of the gluten. As we have seen, the disulfide linkages are responsible for the high molecular weight of the glutenin fraction, and they are involved in maintaining a particular shape for the gliadin molecules. Cleavage of the disulfide linkages quickly destroys the cohesive elastic properties of wheat gluten. Disulfide linkages undoubtedly function in several ways to control and modify gluten protein properties.

In Figure 14 we return to where we started, looking at the gluten that we are exploring. Early we divided the field into two areas for more detailed mapping. These were the gliadin fraction that has sirupy characteristics, as shown in the middle of Figure 14, and the glutenin fraction that is tougher and less easily stretched (right) than the original gluten (left).

We have seen that the gliadin is made up of a number of individual proteins whose molecules are relatively small in size and that it consists of single chains of amino acids with internal bridges of disulfide linkages holding the molecules in a folded or spherical form. In addition, the gliadin, as isolated, contains some material which has structural characteristics similar to the molecules in the glutenin fraction. The glutenin contains very large molecules in which individual chains of amino acids are linked one to another by disulfide bonds and may, in addition, have loops resulting from internal bridging by disulfide linkages. Molecules of both the glutenin and the gliadin show a strong tendency to aggregate or stick to one another. A number of features of structure obviously are involved in the properties of these proteins.

In our explorations we have added a number of points to the growing map describing the gluten complex. Many other research workers are adding their contributions. All of us are looking forward to the day when this map will be complete, and we can feel that we have a complete understanding of the gluten proteins and of the relationships between structure and properties. As such knowledge develops, we are confident that we will acquire the ability to control and utilize the properties of gluten proteins, and of the wheat products containing these proteins, with greater effectiveness.

WHEAT PROTEIN PROFILES FOR QUALITY DIAGNOSIS

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A new technique that has come to have great value in hospital laboratories as an aid in diagnosing a patient's disease is called zone electrophoresis. In spite of the imposing name, it is fairly simple. A small amount of blood serum from the patient is place on a strip of filter paper or cellulose acetate. Voltage applied across the ends of the strip causes the serum protein to move at different rates. After a time the operation is stopped, and the proteins are located by staining with a dye. On Figure 1 at the left is a series of such patterns. Most of them represent normal samples, but the third and sixth might have come from patients with such diseases as viral hepatitis and rheumatic fever, respectively. The patterns on the right represent hemoglobins from whole blood. The first two are normal, and the others indicate various types of anemias.

You can readily see how this sort of thing might be used to predict quality of wheat flour proteins. One must assume that some of the quality factors are related to wheat proteins, but there is good evidence that this is true for baking quality at least. One might hope then that flours that are good for bread would always be high in some one protein or group of proteins; or there might be a characteristic ratio of one protein to another. For

diagnosis of diseases by electrophoresis of blood serum, determination of only 5 or 6 proteins seems usually to be enough. However, until we know more about the importance of particular flour proteins, we must aim for separation and determination of as many as possible. Hence we start out by dissolving most of the protein out of the flour; and we carry out the electrophoresis in a gel rather than on paper. This is a much more powerful separation procedure.

The analytical procedure was developed under a contract with the Western Utilization Research and Development Division, USDA. Briefly, the flour is extracted at low temperature, usually overnight, with a solution of aluminum lactate, using more solution for high-protein flours. In this way from 75% to over 90% of the protein is brought into solution, and experiments indicate it is representative of all the protein. The gel is made by pouring a solution of a synthetic chemical, acrylamide, into a mold where it sets up as a transparent gel in strips. Figure 2 shows the partially assembled mold. Gel forms

Figure 1. Examples of diagnostic electrophoresis of blood sera and hemoglobins.

Figure 2. Partially assembled electrophoresis gel mold.

in openings between sections. Between gel strips cooling water is circulated, so that a fairly high voltage can be used without overheating. A small square peg projects into the gel while it is setting. Afterward it is removed, leaving a slot into which the flour extract is added with a micrometer syringe (Fig. 3). Figure 4 shows the set-up during the actual operation. The voltage is applied to these electrode chambers which make contact with the gel strips by pads of filter paper soaked with the buffer salt solution. About 650 volts are applied for 2-1/4 hours. The proteins start near the top and move downward toward the negative pole. The apparatus is then taken apart, the gel strips are removed and soaked briefly in a solution of a dye which becomes bound by the protein. After the excess dye is washed out, one gets strips with a pattern of protein bands (Fig. 5). The strips are then analyzed in a densitometer (Fig. 6).

Figure 3. Introduction of sample to slot in gel mold.

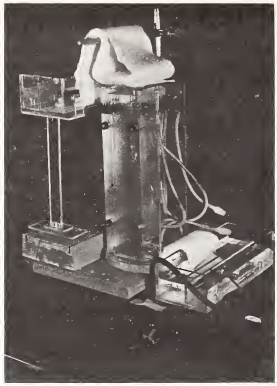

Figure 4. Arrangement of apparatus for gel electrophoresis.

Figure 5. Typical gel electrophoresis pattern of wheat flour proteins.

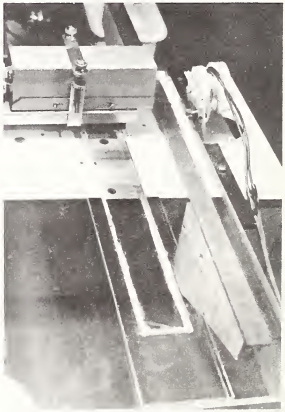

Figure 6. Densitometer for measuring the color depth of protein bands.

The gel strip passes between a light and a photoelectric cell which measures the amount of light absorbed as it passes through the different parts of the gel. The light absorption of the bands is recorded as peaks on a recorder chart. A typical densitometry record, in this case for Rio wheat flour, is shown in Figure 7, along with the corresponding gel strip. Some of the bands

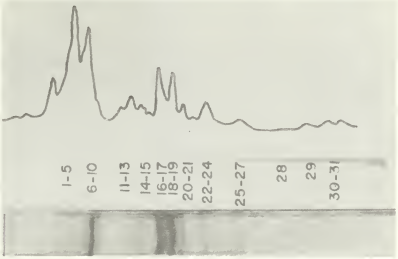

Figure 7. Protein profile of a sample of Rio wheat flour as recorded by densitometry and compared with the gel pattern.

are represented by distinct peaks, others by bumps on the sides of peaks. By running for longer intevals so as to spread out certain crowded areas, we have been able to count at least 31 bands from an ordinary blended wheat flour. Each has been given a number. Theoretically the area under any peak is proportional to the amount of protein. However you can see that the only practical way is to measure areas under groups of peaks. This can be done with a planimeter, which counts the number of times a wheel revolves as you trace the outline of the area. There are a number of complications in working out the proportionality of the area to the actual amount of protein, and this is a part of the method that we haven't worked out to our satisfaction. For instance some of the proteins bind a lot more dye than others. Because of such complications, results will be reported here only in relative terms.

We haven't made any systematic study of the relation of the protein profile to quality. Most results I can tell you about have come from survey studies to get an idea of the range of variation of wheat flours. For instance, we have run gel electrophoresis on flours of wheats of various market classes and the analyses are in Table 1. For comparison the protein level of peak 16-17 has been arbitrarily set equal to 20 for all the flours. This peak seems to be consistently prominent in all samples. We believe it is risky to make too much of a point of all the differences that appear here, but those between the slow-moving peaks 1 to 10 of Itana and Thatcher seems to be striking. Less conventional varieties have shown much more obvious differences. For example, durum wheats seem to have relatively little of the slow-moving proteins, while some experimental Hungarian wheats (Bankuti) of interest to our Agronomy Department have tremendous amounts of the proteins represented by peaks 1 to 10.

To get flours of very high protein content we have gone to some fractions obtained by air classification of a Brevor flour (Table 2). While you might

Table 1.--Protein profiles of some flours of various market classes

		Peak numbers					
		1-10	11-15	16-17	18-21	22-27	30-31
		Relative protein content					
Itana	HRW	430	70	20	25	24	1.3
Rio	HRW	240	53	20	21	26	0.9
Triplet	SRW	230	48	20	28	20	--
Henry	HRS	261	52	20	33	27	--
Thatcher	HRS	144	70	20	25	31	0.6
Burt	HWh	300	49	20	19	18	0.6
Idaed	SWh	257	74	20	32	28	1.0
Federation	SWh	206	48	20	28	12	0.2

Table 2.--Differences in protein ratios in air classification fractions

Sample	% protein	% of total protein represented	Peak area ratio 1-10/16-20
Parent Brevor flour	9.1	100	4.4
Fraction 1	34.2	20	3.8
Fraction 3	17.3	36	4.1
Fraction 7	3.4	9	1.4

expect the 34% to be different from the 3% protein fraction, I don't believe this has been previously shown. I have seen one published study in which the researchers were not able to find differences. You can see here that the low-protein fraction has relatively much less of the slow-moving proteins. This can be seen in the densitometry charts for the two fractions (Fig. 8).

Figure 8. Protein profiles of high and low-protein air classification fractions.

One of our most interesting results has to do with the differences between wheats grown outdoors and indoors. We needed to produce more than one crop per year, and so we grew some spring wheats in the field during the regular season, and the same varieties in a growth room during the winter. The growth room was lighted on a day-and-night schedule more or less corresponding to normal seasonal change. The brightness of course didn't correspond to sunlight, but was adequate for good growth. The temperature was controlled and changed for days and nights, and also according to normal seasonal change, though the temperatures we used would have meant a cool season. The wheat was

grown in pots in ordinary soil, watered and fertilized regularly. Development and ripening seemed to proceed normally.

The protein profiles for the field-grown and growth-room-grown wheats from the same batch of seed are however drastically different (Fig. 9). The Federation flour from the growth room has much more of the proteins represented

Figure 9. Protein profiles of field-grown wheat flours as compared with flours from wheats grown in the growth room.

by peaks 16-17 and other faster-moving proteins, and much less of slow-moving proteins 1-10. If the amounts of peaks 16-17 for the two samples are set arbitrarily the same at 20, the field-grown wheat has over six times as much of proteins 1-10. This Federation wheat was field-grown at Pullman, but you can note that a similar sort of difference occurs between growth-room-grown Thatcher and Thatcher grown at Lind in the much drier wheat-growing area of Washington.

We don't know yet what environmental factor or factors is responsible for this difference, but it certainly is a matter of importance, and a means exists for studying it by controlled experiments. This opens up the possibility of achieving a thorough understanding of the chemical basis for quality as related to growing conditions.

Finally I want to describe a study we're now carrying on under a new contract with the Western Utilization Research and Development Division. It illustrates another use that can be made of our analytical method. We're studying changes in flour proteins during dough mixing and fermentation, using radioactive tracers. The wheats I have described, grown in the field and in the growth room, are used. One can produce wheats with radioactive proteins by injecting amino acids containing carbon-14 into the stem at the soft dough stage. At this stage the wheat plant is most actively building amino acids into proteins. The radioactive flour will be subjected to gel electrophoresis, and groups of proteins (for example, peaks 1-10 or 16-20) will be separated,

and according to present plans, dissolved from the gel and recovered. These separated radioactive protein groups will be added one at a time to nonradioactive control flours. They will be mixed as doughs, and protein profiles will be made before and after mixing. By studying the relationship of radioactivity to the protein profiles we will learn what happens to proteins during dough mixing. The same sort of experiment will be done for dough fermentation.

The main thoughts I would like to leave with you are that wheat flour proteins are complex. We have most of the problems worked out and have done enough to be convinced that the procedure will be valuable, not only for studying and controlling both varietal and environmental influences on wheat quality, but also for studying the true basic reasons why proteins affect quality--for example their effect on development of dough during mixing.

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